

ENGINEERING ECONOMICS

BOOK II WORKS ORGANIZATION AND MANAGEMENT

BY
T. H. BURNHAM
B.Sc. HONS. (LOND.), B.COM. (LOND.), F.I.I.A.
A.M.I.MECH.E., M.I.MAR.E.



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mentals of works organization and management as an introduction to a systematic preparation for industrial responsibility, and in particular to cover the chief features of the syllabus for the A.M.I.Mech.E. Examination, Section C. It may also be of service in connection with the examinations of the Institute of Production Engineers.

T. H. BURNHAM.

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BOOK II
WORKS ORGANIZATION AND
MANAGEMENT

ENGINEERING ECONOMICS

CHAPTER I

THE MANAGEMENT FUNCTION

INDUSTRIAL MANAGEMENT

IN the previous book we saw that industry has been completely transformed during the last 150 years or so. A series of brilliant mechanical inventions led to the rise of the factory system followed by a revolution in transport. The alteration in the structure of industry necessitated its organization on new lines to cope with its enormous expansion, but until the last quarter of the nineteenth century industry was expanding so rapidly that the question of costs was usually in the background. With increasing competition from Continental countries the importance of reducing real costs of production came to be recognized, and trained engineers began to study the problem of organizing men, machines, and production on a scientific basis.

Management began with the advent of capital, but the development of the joint-stock principle tended to separate ownership from management, and the rise of trade unionism gave the latter a new orientation. Although the structure of industry appears to have grown up somewhat haphazard, there has evolved a science of industrial administration, which seeks the ideal of maximum efficiency. The quick levelling up of technical information makes production more and more a method of skilled management. It is no longer based on empiricism, but embraces certain fundamental conceptions of undoubted truth and universal

applicability. It is not possible to formulate the principles of management in a few statements, but we may briefly consider what it is, how it developed in industry, what the problems are which confront management, and its present trend of development. There are certain underlying or fundamental rules of production efficiency which management uses, such as division of work, division of effort, the transfer of skill, simplification and standardization, task standardization and scientific methods of wage payment, responsibility with authority, and so on, but management embraces more than this, principally the quality of leadership.

WHAT MANAGEMENT IS

There are three types of mentality, the controlling or leading, the scientific or technical, and that of applied labour. The manager belongs, of course, to the first. The creative energy of capital and labour is powerless unless the man of leadership ability organizes them.

Management may be defined as human engineering, or primarily the art of directing industrial activities. In a factory we see the plant and the product, but not the ruling force which directs and controls production. It is that art of getting things done, the unseen creative force, which drives a factory or other enterprise. It, therefore, demands for its successful operation the ablest, most daring, and most energetic of men, inspired with the idea of achievement. In addition to a practical knowledge of industry, the need in management is for courage, clear vision, and quick decision. Systems are not a recipe for success. There are no secret processes and no magic formulae. Because someone else is doing something successfully it is not safe to follow blindly. What we require to know is: Is the manager managing or is he being managed? Is the director directing or is he being directed? There is no leadership if the leader does not know what and where he is leading.

The mental attitude of management is one of research,

of analysis, of seeking exact knowledge, and of shaping action to the discovered facts.

Management must be open to new thoughts and methods, and receptive to the proposals of subordinate technicians. In the past there has been too little readiness to change.

The development of industry has been a remarkable story of scientific achievement, the priceless gift to humanity of magnificent productivity, but may it not be legitimately asked whether the organizers and managers of our industrial activities have not made a more important contribution to the physical and social well-being of the race? The standard of life of the population depends on the initiative and skill of those who conduct its enterprises.

Management is something more than the art of getting things done; it involves all the non-physical factors in the operation of an enterprise and the correlation of the details into a harmonious whole, generally with a view to earning profits in the maximum possible amount. It embraces the establishment of the policy of a business, the planning of its organization, the conduct of its operations, and the control of its personnel.

Management has a technical and a non-technical side; the first includes methods of manufacture, production and control, invention, design, specifications, and so on, and the latter the commercial and financial aspects of the business. The importance of the financial side of industrial management is seen at once when it is remembered that most plants are operating with borrowed capital. Banks appreciate good management as a business factor, and able management, sometimes even the reputation of the managing director, will largely determine a plant's value. Management, in fact, reaches beyond the developing and operating of plants, beyond the problems of production, into those of administration and the higher executive functions, face to face with the greater problems of human relations in industry.

DEVELOPMENT OF INDUSTRIAL MANAGEMENT

When we come to consider the historical background of industrial management, we find that the form of relationship between executive and worker with which we are concerned to-day is not much more than a hundred years old. It has been indicated how the Industrial Revolution led to the growth of the workshop and development of the factory system. Later on industry became organized into large groups and interests for the purpose of realizing the benefits of capital aggregations. Modern management methods are the natural outgrowth of advances in industry since the invention of the power spinning-frame and the steam engine. Briefly summarized, these advances may be considered the following: After improvements in mechanical devices a period followed of adjusting the manufacturing process to the required product, and finally the co-ordination of the entire mechanism of production. Changes in technique and production methods through division of labour, and in organization through specialization of businesses, have led to mass production and groups of factories with a common management, and have necessitated centralized control.

We have noted with the growth of the joint-stock system the separation of management from ownership of industry, which retains only the function of ultimate control. Ownership is being spread on an ever-widening base and must operate more and more through management. The burdens of responsibility have caused specialization in management; it is too much, for example, for one man to be expert in the functions of designing equipment, operating plant, purchasing, selling, accounting, and so on. Management, therefore, should be shared by technical and non-technical men respectively, and not allotted solely to men trained in the commercial and financial branches of business, a practice far too frequently employed hitherto. Technical men must, however, recognize the over-riding importance of the economic viewpoint in engineering

and manufacturing processes. Decisions in the management of any business are always based on economic analysis.

Although scientific research on the practical application of technical principles to industry was commenced at Anderson's College, as long ago as 1823, the so-called scientific management movement is not half a century old. Two of the most vital questions of industry are production and cost, and it should be noted that the management movement was initiated by engineers intent on solving problems of cost and wage systems.

THE WORK OF F. W. TAYLOR

Attention was first directed to scientific methods of increasing the effectiveness of manufacturing operations by the American, F. W. Taylor, who endeavoured to lay down definite principles and elaborate the technique of management. His work was taken up by others, such as Gantt, Emerson, and Gilbreth. Incidentally, it should be mentioned that before this work had proceeded very far it became clear that factories were not correctly designed or arranged to make the most of the possibilities of operation.

The reasons for accentuated interest in management towards the end of the last century are not hard to find. The average efficiency in a large group of industries was found to be very low, due to obsolete craft regulations and customs, unsuitable tools, haphazard engagement of workers, the absence of planning and reliance on rule-of-thumb, and very simple changes in the arrangement and progress of work had the effect of considerably increasing output.

As the size of plants increased, personal contact and the power of supervision lessened, so that other incentives to stimulate interest and effort were sought. Increasing competition necessitated the accurate analysis of costs and

enforced attention to systematic organization, co-ordination, and regularization of production.

F. W. Taylor laid the foundations of his important contribution to the science of management between 1880 and 1890. In 1882 he joined the Midvale Steel Company and set himself to answer the difficult question of what should constitute a day's work. It was here he carried out the famous experiments on metal cutting, resulting in the development of high-speed steel. In 1898 he entered the employment of the Bethlehem Steel Company, and at this period carried out his classical experiments on shovelling and pig-iron handling, and developed his wage-payment system. He endeavoured to find out the best way of doing a job so as to eliminate waste of effort, time and material. Taylor was not good at generalizations, but he laid down certain fundamentals which he held to be the true basis of shop management. They may be summarized as follows: each element of a man's work should be accurately and minutely studied; for each particular job the best workers should be selected and then carefully trained; the management and men must co-operate in the productive processes; departmentalization is not only important but essential.

Taylorism, however, had many defects, and interest in it gradually waned. In the first place, teaching anyone to be efficient is not popular, but the efficiency men appointed under this system were sometimes particularly objectionable and ruthless. Extravagant claims were made, and some of the industrialists first to adopt the system were too impatient for results. It has the demerit of largely neglecting the human element in industry, and in this connection it may be mentioned that the Taylor wage-payment plan, with its tendency to over-drive, badly penalizes the slow worker, however conscientious he may be. There may also be a tendency under Taylorism to give such close attention to details that the broader aspects and larger factors in industry are overlooked. It should be

remarked that Taylor's scientific management as a system has hardly touched this country at all.

Nevertheless, it must be freely admitted that Taylor was a true pioneer and did great work. He concentrated attention on the need to apply to management the care and constructive ability which had characterized advancement in mechanical invention and other lines. His work has been discussed almost to wearisome length, yet little that is fundamentally new has been added to it. This is readily appreciated by referring to the papers presented to the Sixth International Scientific Management Congress in London in 1935, which appear to constitute little more than an elaboration of Taylor's "principles."

It should not be forgotten that it was Taylor who emphasized the importance of the systematic use of experience in management. He insisted on the separation of planning and executing work, recommending consistent planning based on scientific analysis by a special department organized for that purpose. He originated the functional type of organization in which each sub-manager or foreman was entirely responsible for a single line of effort. The training of workers in the best possible methods was an essential part of his practice. He also insisted that the only equitable system of wage payment must be based on the quantity or quality of work performed.

MODERN SCIENTIFIC MANAGEMENT

Scientific management may be used in a narrow sense to relate to the organization of human effort in a factory, or in a wide sense to cover the whole sphere of business enterprise.

Scientific management is an attempt to determine and apply the facts and laws that underlie true efficiency, embracing the following in its analysis: the best situation and construction of shops, the most effective character and arrangement of machines, tools, and materials, the most

efficient productive processes, the best methods of selecting and training men and the nature and amount of work that ought to be performed by each, and the most suitable method of payment in the interests of the individual and of efficiency. Works management has to be considered, however, in relation to the ever-shifting struggle of practical affairs, and has to determine the most efficient combination of the various factors of production to be utilized in a going concern under given market conditions.

Formerly markets were of secondary importance; planning was only applied to production, but an era of economy arrived when mere volume was not sufficient to show profits.

At the present time scientific management is taken to imply that, based on an accurate knowledge of the market and ascertained facts, an annual forecast of probable sales is made and production planned to meet this forecast. Operations are then controlled and corrected, if necessary, at frequent intervals to meet the sales position as it develops. The management mechanisms available for economic production may be summarized as follows: market analysis, budgetary control, stores control, process and operation analysis, planning and scheduling, production control, quality control, labour incentives and control, cost control, and maintenance control. Production in itself is not sufficient; it is the economic results which matter; everything must be brought to the touchstone of commercial success. The importance of forecasts as an aid to management cannot be over-emphasized, not only of sales but of production, costs, expenses, profit, and so on, and the more "scientific" the management the closer is the agreement between the forecasts and the facts. Scientific management is a larger question even than rationalization, though it would adopt a policy of rationalization if the facts warranted it.

The complexity of modern business increasingly necessitates specialization of function.

DIVISION OF MANAGEMENT FUNCTIONS

It is customary and generally essential when an industrial concern has grown beyond a certain size to subdivide the higher executive functions into administration, management, and organization. In order to clarify the function of the manager we may briefly distinguish between these. Administrative problems involve the establishment of the business or enterprise, the determination of its purpose and policy, and its relation to the rest of the industry. On the board of many industrial concerns will be found men with no particularized knowledge of the industry itself, but with a wide general business knowledge and experience which make their services in an administrative function of very great value to the undertaking. On the other hand, there is now a tendency for the executives engaged in high finance to become involved in the technique of the business. The administration or higher control attempts to achieve the objects of the business through management and organization.

The management is concerned with the execution of the policy laid down and the effective employment of the whole organization to attain the objectives. Organization is more directly concerned with combining and co-ordinating the work and efforts of departments and individuals, so that the available productive forces may be utilized with maximum efficiency. Management has to secure unity of effort throughout the organization, ensuring the working of the plan to schedule by co-ordinating mechanical, manual, and mental effort.

The problems that confront management are to run the concern at a profit by creating commodities of the required quality in marketable quantities at the required time by the best and cheapest methods, and to exert industrial leadership and establish goodwill and harmonious industrial relations. The qualities of executive ability are vision, resource, leadership, and knowledge of human nature.

The managing executive must have a clear vision of the aims of the undertaking, and, having determined the type of organization it requires as its agent in production, must concentrate on the primary objective of control. The essence of modern management is to use scientific methods to replace the old order of uncertainty, chance, and fortuitous results. This systematizing of operations and results is secured by fixing responsibilities, the task given to each man being within his powers, and ensuring that responsibility is accompanied by authority to control the means of doing work.

Planning, which will be considered more fully in a later chapter, should be a characteristic of every section of a business. For the proper functioning of the managerial machine, working to schedule is essential.

Specialization of individuals produces the same results as specialization of machines, viz. increased efficiency, and particularly is this the case in specialization of management. The higher control must bring out the best efforts of the managing staff and secure effective co-ordination and co-operation so that all executives pull in a straight line. It must ensure that the work controlled by each member is within his power, so that the risk of breakdown of programme is avoided. In addition, the contact of executives with the workers must be real. The higher control must see to it that friendly relations with the labour force are maintained. It cannot be over-emphasized that wise leadership is more essential to the success of any enterprise than an extensive organization or the most up-to-date equipment. It is a commonplace that good executives are scarce; this is probably because the faculty of seeing, or rather foreseeing, clearly is rare. The ability to visualize a proposition and all that it means, all that must be accomplished before the task is achieved or the business completed, so as to have a fairly accurate estimate of the cost, demands brains of the highest order. In the world of business, however, some of the biggest deals are put through

as the result of a brief talk between principals. The clarity of a man's vision is indicated by the clearness and accuracy of the orders or instructions which he issues; and it may be laid down that no man is capable of being a leader, or, in other words, a manager, unless he knows what is to be done, how, where, and in what manner it is to be performed, and unless he can issue clear and unambiguous instructions to this effect and assure himself that they are being carried out in accordance with the schedule he has laid down. He must give prompt decisions, fairness, and a square deal. One of the essentials of management is justice, but there can be no justice if there is no knowledge. Direction comes best from a single mind, thinking constructively and unhampered by unessential detail. In the higher planes of management there is no place for democracy. Shaping policy by committees is difficult, if not impossible. Managerial attention should be concentrated on executive matters; if it is given to routine questions, either the manager is inefficient or the organization has broken down.

THE MANAGING DIRECTOR

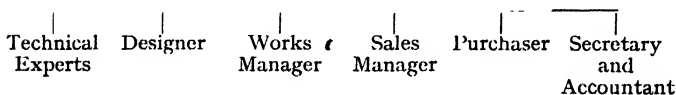
The highest co-ordinating position is occupied by the managing director. He must see the enterprise as a whole, as administration consists of carrying on a series of closely related functions, all of which are co-ordinated. He must have a sound knowledge of the human sciences, sociology, physiology and psychology in their bearing on industrial relations.

His true function is making decisions, but they must be made with full knowledge of all the circumstances. Without it his efforts to plan, organize, direct, co-ordinate, and control are not likely to meet with full success. Directive management problems are always difficult, involving the selection of new ideas, patents, markets, and processes. Decisions require the impartial weighing up of a large number of factors, and must be made at once, though accomplishment may be deferred for years.

The managing director of a firm is always looking ahead, and in the execution of his special function, an economic adviser, can often render considerable service. Policy is, of course, determined by many considerations, but the more readily economic facts and trends are at the disposal of management, the more intelligent and trustworthy that policy will be. The new function of administration is to eliminate the element of surprise from business. The successful business man anticipates the future; this is sometimes called flair, but generally means a sound perspective based on knowing the past and the present.

In a manufacturing concern the higher control consists of the managing director and perhaps the works manager, for even if the undertaking is designed on functional lines, as follows, the manager of the manufacturing division may be compared to the trunk of a tree and the other managers to the branches.

MANAGING DIRECTOR

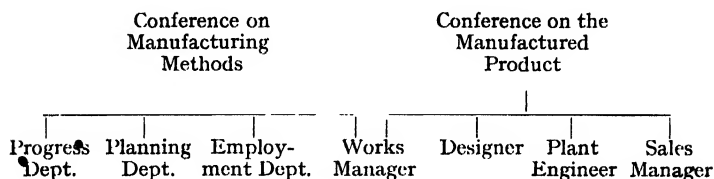


The managing director is the centre or hub of the undertaking, responsible only to the board, and to him are responsible the works and office managers and the various legal and technical experts of the firm. He focuses the executive interests of the board of directors and moulds the form of organization to the needs of the enterprise. He delegates his authority to his staff, concentrating his attention on his own function of leadership.

The managing director will spend a proportion of his time in conferences, at which he will be required to make decisions on the evidence put before him by the various experts and managers, and it will be found that the works manager is also present at the majority of these; in fact,

he is more or less concerned with everything that goes on in the works. The following will serve as an illustration of works conferences—

MANAGING DIRECTOR



Of course, other officials than those shown will attend the conferences, and in practice it is often found that these conferences succeed each other continuously, but whilst various managing officials may come and go, the general manager and the works manager stay throughout.

THE WORKS MANAGER

The works manager is the centre of a group whose activities extend throughout the plant. He carries the responsibility of producing the planned output with the maximum efficiency and of the desired quality, using the works as his tool. He does this by issuing the requisite orders to the heads of the manufacturing or other departments concerned. He is responsible for the factory, plant, manufacturing labour, and working to schedule. He deals with all matters of general policy affecting the works and, whilst keeping in personal touch with all technical matters affecting the operation of the plant, he may or may not make the question of personnel his immediate concern. There is a tendency to make a distinction between personnel control and operation technique, but in this country the general practice is for the works manager personally to select his operating staff.

‘He must see* that the works functions as a whole with maximum efficiency, and that it also operates economically. To this end he must departmentalize the works, building up* the organization and welding it together into a harmonious whole.

His functions are so important that it is usually better to dispense with a works manager’s services altogether than to interfere with his work in any way. If there is a management committee it should act in a purely advisory capacity, and a works manager should not be compelled to adopt the recommendations of the functional staff against his judgment.

To be a master of the technique of production is not a sufficient qualification. The other essential is the art of individual leadership.

The works manager must obviously be a technical man, but he must be something more than that. He must be a man of outstanding character, justice, and vision, capable of inspiring enthusiasm, and broad-minded, having initiative, and sensing the broader activities of the business. The manager must not only have power as a leader, but the ability to stimulate effort in others. He must be an energizer, giving clear instructions and making prompt decisions. He must know human nature, be a good judge of character, and capable of working with as well as over men; in other words, he must be something more than a disciplinarian; he must be capable of obtaining co-operation and co-ordination of effort. He must inspire respect as he sets the tone and creates the atmosphere in a works. Good organizations are built up round personality, not knowledge.

The works manager must have the ability to negotiate harmoniously with all those with whom he may come in contact. Whilst he must actually lead the departmental heads, he must delegate authority and should allow his subordinates full powers inside the limits of their discretion and clearly defined duties. They must be trained to

tackle their own problems and make their own decisions. Each official must be made to feel the full weight of his responsibility. Interference by higher officials with departmental functions or the over-riding of instructions given by those in charge of sections must not be tolerated. It is also a trait of good management to disclose fully to subordinates all the facts which have a bearing on their work, directing their energies and finding outlets for their ambitions towards a common goal.

The manager must see to it that he keeps in touch with actual facts and not become a mere reader of reports. It is easy from reports to know everything after it has happened. He must not only be an expert on the manufacturing operations so as to provide the best-suited machines and tools in the best possible condition and arrangement, but also ensure that the right materials are obtained and available when and where required. He must know what ought to be accomplished, what is actually being accomplished, and the efficiency with which every operation is being performed. He must be continually studying possible improvements in machines, methods of operation, products, labour costs, and so on, looking ahead for possible reductions in cost. He will pay careful attention to the keeping of reliable records, so as to have immediately available all matters relevant to production, such as total output, production per man, wages, proportion of day work to piece work, overhead charges, materials consumed and wasted, total costs, occupied and unoccupied floor space and machines, proportion of wasted time and broken time, and many other data which are essential for him to know. The importance to management of continuous, prompt, and accurate information on what the enterprise is doing, and what can be expected, cannot be over-estimated. Facts must be analysed as well as collected so as to synthesize and understand them with a view to devising plans of action.

A works manager will also endeavour to make personal

contact as far as possible, because he will be interested in the safety, comfort, and welfare of his men, and know that individual recognition is a great asset in stimulating successful human relations in industry. His endeavour is to co-ordinate the work and the workers into a correctly functioning whole. His success depends on engendering a group power.

EFFICIENCY OF MANAGEMENT

All firms are in the same market for materials and labour, and probably plant; differences in their costs lie in organization and the use made of time and the control of expenses. Thus maximum efficiency in management is essential to economic survival.

It may be asked whether it is possible to devise any measure of the efficiency of management. It is difficult to suggest a criterion, for it can only be measured over an appreciable period of time and involves setting a standard on which there is little or no agreement. The usual and obvious way is to compare the profits made by the enterprise with the average or representative profits made by firms in the same industry, but there are, of course, many other factors which enter into profits besides managing efficiency. The true index is perhaps the ratio of profits actually earned to the real profit-making possibilities of the business. There is, however, no one figure or ratio which can be taken as a pointer that the management is getting the optimum out of every £1 invested and every man employed. Efficiency implies that the management is making full use of all agents of production. A number of factors may be expressed as ratios and an overall view taken. A number of these ratios were considered in Book I when the information obtainable from a balance sheet was discussed. Others are --

Profit earned on turnover.

Net profit on turnover.

Volume of business to total capital employed, and so on.

Profit or loss consists of two groups of items, those arising from manufacturing operations and those external to manufacture. Ratios which more directly concern the works executive are operating efficiency, or operating profits on the capital employed, and trend of operating results, or cost and expenses over value of turnover. We may say, however, that a works manager is being as effective as he possibly can when each department of the works is properly correlated with every other, and each division is working at a maximum efficiency. He will continually be endeavouring to make the optimum use of materials, plant, and men; the most satisfactory materials for the purpose in view will be worked up without waste, machines will be continuously employed at the most efficient speeds, and the men will be working without interruption to a schedule which experience has established as a maximum that can be maintained without harmful long-run effects. Planning is the keynote; each phase of the manager's duties will be directed towards raising or maintaining the effectiveness of the various agents of production. It has been shown that high efficiency is developed in a works by supplying the men with the best procurable equipment, ensuring that they work under the best possible conditions, and supplying a wage incentive related to the quantity or quality of output.

A high standard of management is no casual attainment, but a complicated science, and in a works manager involves a sense of the economic process of production. It is one thing to install efficient methods and another to prevent any slipping back into the old costly ways. The point to remember is that efficiency depends on leadership.

The corporate efficiency at which management must aim includes not only individual efficiencies and the association of efficiencies, but also the true efficiency which comes from enlightened reasoning and a higher motive. There is no essential antagonism between the making of profits and full co-operation between management and employees.

INDUSTRIAL RELATIONS

In some quarters it is considered that industrial relations are the supreme test of management. The watchwords of the nineteenth century were competition, commercial antagonism, and class warfare. In the present century the keynote of industrial relations is co-operation. Certainly it may be granted that to find in any undertaking cordial and responsive workers giving willing and intelligent help in the accomplishment of the aims of the management goes a long way towards conviction that the latter is carrying out its onerous duties in an efficient manner.

The Great War had a well-marked effect on management as on nearly every human activity. After the first period of shock and maladjustment it was realized that the urgency of the demand for war materials necessitated organization on a scale hitherto unattempted. The most experienced managers and the greatest experts in the country were called together and given a free hand to increase production as rapidly as humanly possible. In order to obtain the maximum sustained effort from the operators, both male and female, the effect of all physical factors bearing on production was carefully investigated, including workshop conditions, processing of work, fatigue, and so on. A great deal of valuable management experience was accumulated, newer and broader conceptions were developed, and the importance of the human factor in industry was shown up in strong relief.

In the post-war depression the emphasis was transferred to other management problems than production. The vital necessity was for sales, and to achieve these it was imperative for the manufacturing division to reduce operating costs.

Waste, in either processes or materials, had to be eliminated, greater efficiency developed at every stage, and better correlation of departments. This was the only alternative to drastic wage reductions and unemployment. So severe was the crisis that only well-managed firms

passed through it without severe losses or capital reduction. With the slow return of normal conditions, interest is again centred in increasing production as a means of establishing a favourable basis for competitive selling. •

Modern industrial development is characterized by growth of markets, large-scale production, the diffusion of ownership, the separation of ownership from management and the rationalization of industry. Rationalization gives the administrator the task of organizing and correlating businesses instead of departments. It raises the spectre of technological unemployment whilst labour is calling for the evolution of some new industrial constitution. As the size of business units increases from either integration or combination, industry has to be carried on in accordance with master plans and schedules, and managements have to take broader views, taking into consideration circumstances which they might previously have held did not concern them.

- Rationalization has been blamed for over-production, but this only confuses the issue. Certainly progress in science and industry has achieved amazing productivity, but increased productivity may outstrip even increased demand, resulting in lowered employment. The trouble appears to be in distribution and, in particular, in the development of purchasing power. The total of goods that could be produced is enormous. The trouble is that they could not be bought. It has been suggested that the instruments of man's creative power have outrun his effective co-ordination and control. Others, however, suggest that not less rationalization, but more, is required, provided it embraces not only the internal organization of private undertakings, but the whole economic and social activities of the country. Whatever may be the solution of this problem, it entails vast changes in the organization and control of industry. In any case, it may be accepted that for success in this machine age, it is essential to eliminate waste not only in production and distribution but in administration

and finance. To this end good management is the most important and dependable factor in the prosperity of a business.

In recent years there has been a greater appreciation of the vital importance of management, and a belief that whilst some men have an innate gift of leadership, the fundamentals of successful management can be taught or imparted and latent ability developed, as witnessed by the inclusion of the subject in the curricula of universities and technical institutes, the growth of management societies, the larger number of conferences, and the increase of books and periodicals dealing with the subject. Empirical methods of management have gone for ever. Management is now something more than an art, though the personal element will always be the most important factor. It is a highly skilled activity, the methods and underlying philosophy of which may be advanced by the application of scientific methods. It is becoming a skilled profession, demanding not only high qualifications but preparation and training.

MANAGEMENT RESEARCH

Research is not confined to the laboratory or works, but should extend throughout the whole activity of a firm. Management research is as indispensable as an economic weapon to keep abreast of progress as research on materials, equipment, processes, and designs. Few errors could be more grievous than to stop research short at physical subjects and not pursue it in the science of management, works organization, and the human factor in industry, as well as in marketing, distribution, and other branches of the commercial division.

A manager must continually modify and adapt his procedure to the ever-changing panorama of industrial, legal, and economic circumstances. Hundreds of firms throughout the country must be confronted with the same or similar management problems. To ensure contact with the

most recent managerial procedures in practice, interchange of experience and cross-fertilization of ideas is not only desirable but essential, and most easily achieved by membership of one or other of the Management Research Groups.

FACTORY ORGANIZATION

The domestic system of industrial organization came to a close with the eighteenth century, when the factory system developed as the result of the Industrial Revolution. From that time production grew on an increasing scale, and the first decade of the present century witnessed the establishment of large-scale industry, which has been further advanced by the expansion of markets and the new force of advertising. Although production can be carried on economically and successfully in small units, manufacture on a large scale is tending to become the typical form of industrial structure. The increasing technicality of industry has made skilled management indispensable, and the problems of organization and control are becoming more complex.

The importance of small-scale industry in this country must not, however, be overlooked. The small enterprise without any spectacular form of organization often attains a level of efficiency which enables it to compete successfully with the large concern. The small factory has a special sphere of utility, and may possess distinct advantages where varied products or special designs are required, or where close supervision or elasticity in operation is necessary. It should be noted, moreover, that many of the great captains of industry have graduated from the small factory, and not from the departments of large concerns.

Of recent times the lives of men and nations have been largely determined by industrial achievements, and those who have organized industry most efficiently have prospered most. The object of organization is to create the optimum firm as a productive unit, a marketing unit and

a financial unit. Organization seeks to make the most of material and personnel by devising the most suitable structure according to the work to be done, so that the factory may be run smoothly according to plan, and responsive to the demands of the higher control. Organization may be considered as a process for achieving the ends of the management by the skilled arrangement of plant and efficient interrelation and co-operation of machines and men. It seeks to create an efficient and well-balanced machine, sound in all departments and capable of expansion without dislocation. The systematizing of operations simplifies the actual manufacturing process and decreases the costs of production and distribution.

Organization has been epitomized as follows: Plan, deputize, supervise. It is the primary step in management, otherwise the executives would be overwhelmed by the mass of detail. Having due regard to the size, aim, and objects of the enterprise, the executives must build up a suitable structure and decide the duties, functions, and scope of the individuals engaged, when they are to act, whom to consult, and so on. The fixing of responsibility and definite lines of supervision is generally regarded as the backbone of organization; it prevents overlapping of duties and internal friction. Responsibility must, of course, include responsibility for co-operation and team-work, as well as for the accomplishment of specific tasks. Moreover, the mere assigning of duties does not ensure the performance of the work involved, so that, whilst having due regard to the personal equation, the organization scheme must include adequate control. With a suitable organization no failure to work according to plan, e.g. keeping up to the programme of production or within budgeted expenses, will escape report and rectification.

We have previously referred to organization as dealing with existing plant and machinery, labour forces, and raw materials, but this must not be pressed too far, or some aspects of reorganization may be excluded, which

is sometimes due to advances in technique rendering existing equipment obsolete, though in this case also the function of organization may not be called into play until the planning or other department with similar functions has developed the new working tools.

Apart from the location and site of the factory, the size and cost of building, the output, the number of employees and the number of machines, it is obvious that production methods and operations must be decided before organization starts. When it is laid down who is to be responsible for originating plans and giving orders, it must also be made clear how these orders are to be transmitted; in other words, the chain of authority must be known to all. It is not sufficient to say that the departments must co-operate; the organization plan should show how they are to unite their efforts. How and by whom are materials, plant and equipment, production and finished goods to be controlled? An organization chart shows the lines of supervision and the various areas of individual responsibility. Organization charts are usually drawn in the form of genealogical tables, but there is some virtue in representing departments as triangles, apex downwards, showing that responsibility increases with each rise up the executive scale.

It must be remembered that every step in production demands action on the part of some individual, and that individual must know to whom to look for instructions and the requisites to carry on his work, how far the scope of his initiative is allowed to extend, when he must consult his superior, what he is to do with his work when finished, and so on. In an effectively organized works no one will be left wondering what he is to do in any of these circumstances.

TYPES OF ORGANIZATION

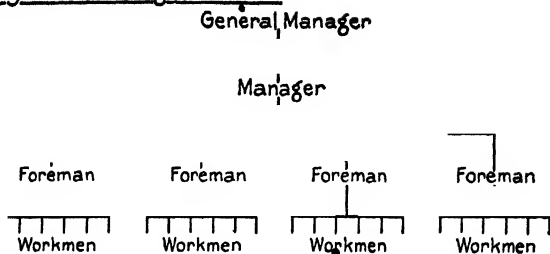
A factory is a dynamic thing and the plan of organization will, of course, vary with the type of enterprise concerned.

The form of organization most suitable for operating a railway is not necessarily the best for building a bridge or ship, and the organization of a concern consisting of many separate but similar branches would be expected to differ from that of a works manufacturing a complex product with many shops engaged on entirely different operations. An organization must be built up and extended to some definite design, and must be elastic, as changes in method usually involve changes in organization. The basic activities of a manufacturing firm are production, design and development, distribution, accounts and finance, and secretarial and legal. These five functions are co-ordinated under the control of the general manager.

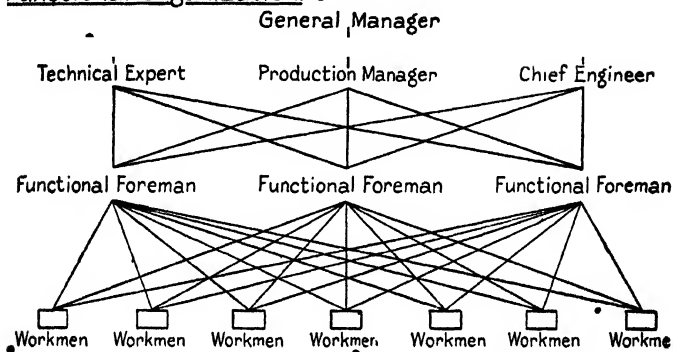
There are three main types of industrial organization, which are described below; sometimes a fourth is added, viz. that involving management by committee or conference, e.g. committees on manufacturing methods, stocks, complaints, welfare, and so on, but this must still be regarded as supplementary to the main organization.

The earliest form of industrial leadership was of the military type. To-day autocratic industrial government is almost impossible, but the method of delegating authority whilst retaining control is known as the line method, i.e. a direct line of responsibility. Authority flows downwards in clearly defined lines. Each department head is responsible for everything within his department, and each intermediate member in the chain of officers is compelled to exercise the several functions of control in "watertight" departments. In this type of organization, the manager and foreman are required to exert so many and diverse functions that it may become almost impossible for them to carry out their duties efficiently. It has the strength of unity of command, but the following weaknesses. It depends on the ability of one man, who has to be a jack-of-all-trades; it induces red-tape methods; information is difficult to pass upwards; and so this type is lacking in stimulation of human effort.

Military or Line Organization.



Functional Organization.



Line and Staff Organization

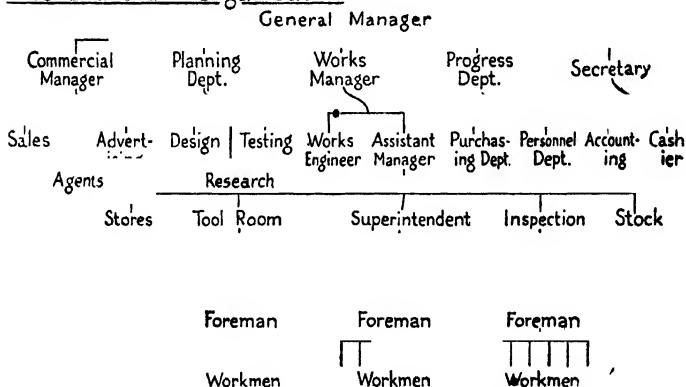


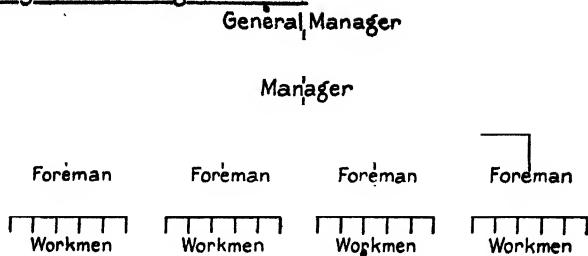
FIG. 1. TYPES OF INDUSTRIAL ORGANIZATION

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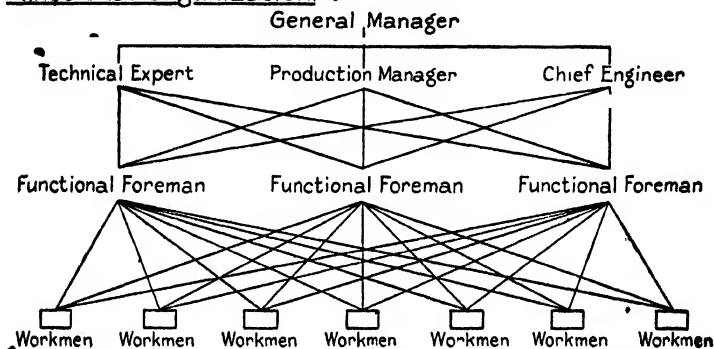
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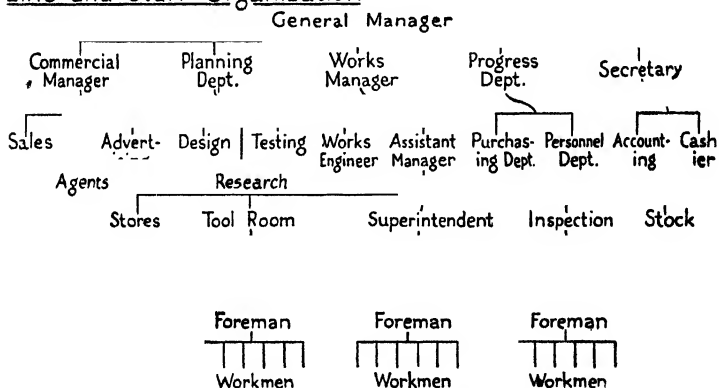


FIG. 1. TYPES OF INDUSTRIAL ORGANIZATION

As organization has developed, two other types have evolved, viz. the forms known as functional and line and staff. The former, which has met with considerable application in the United States, may be said to represent greater specialization and the division of labour applied to shop management. It is based on the conception that the main divisions of the enterprise should be made from a scientific analysis of the work to be accomplished and like functions grouped together. Functional organization marks a true distinction between processes, and separates planning from performance. It is claimed that this method of shop supervision, in which each foreman looks after a different function, facilitates the training of employees, and there is a proper interlocking of job and man, but co-ordination is of extreme importance and demands the constant attention of the executive. It involves, however, much clerical work and sometimes raises clashes of authority, so that if this system is carried very far it tends to become complex, confusing, and unco-ordinated.

The staff and line form of organization may be explained as follows. The staff idea recognizes the value of specialists who think out and study different phases of the business for the benefit of the executive, but the line indicates that authority flows from top to bottom. There are, however, side eddies, as it were, of authority in the staff departments, where skilled specialists are supreme in their own particular field. Thus there is not only unity of command but a meeting ground for ideas and the imparting of special information. A graphical representation of these three forms of organization is given on the previous page. Characteristically, the English method is usually a compromise. The departmental system is often used as a basis with the staff and line and functional ideas used as correctives of its disadvantages.

A good plan of organization of a constructional job is the establishment of focal points, facilitating control. The work is laid out so that each job moves along a route of

operations clearly mapped out, and arrives simultaneously with the others at the appointed place of erection. Co-ordination is the essence of the job, and the various sub-contracts must dove-tail into the main line of work. A work progress chart facilitates the maintenance of the schedule of operations. As a number of labour types will generally be employed on a large construction job, the supervision and co-ordination of the different trade groups will demand special attention.

PLANNING AND PROGRESS

The modifications in organization which are occurring due to the dissemination of new ideas relate principally to the development of the planning department, the progress department, the cost-accounting department, and the functions of foremen. Other factors influencing organization include the growth of standardization of both equipment and working methods, increased attention to the specification of processes and materials, the line layout in contrast with the segregation of similar machines and appliances, and the greater importance being attributed to records and statistics.

Planning and progress departments are the fundamentals of works organization. Consider what happens on receipt of an order by the sales department for the establishment of a production programme. Manufacturing orders are issued to the works manager, the planning department and the progress department. The planning department draws up the layout and operations, specifies the machines, tools, and materials, and issues the operating sheets giving times and rates. The works manager fits the work into the routine of the shops and issues the production programmes. The progress manager sees that the materials and the workmen are available and keeps production up to schedule to give the promised delivery, advising the accounts department when the products have gone.

In the planning department, engineers analyse all

inquiries, with a view to securing the most economic methods of production with the plant available. If the inquiries materialize, the plans are passed on to the works manager to carry into practice.

In Fig. 1 (Line and Staff Organization) the managers of the planning and progress departments have been shown as executives of equal rank to that of the works manager, and in large firms this may well be the case. In many firms, however, the works manager carries the supreme responsibility for production. This has been assumed for the purposes of Fig. 2, which suggests a works organization involving planning and progressing, and indicates the flow of instructions and reports.

Whilst a planning department may represent an overhead charge which a small concern cannot afford, sooner or later in a growing enterprise it will be found that the limit of the capacity of an overloaded manager has been reached, and the establishment of such a department is the only means of grappling with the situation. In large-scale production it undoubtedly renders a real service. A planning department must not be considered as engaged on work that would not otherwise be done. Somewhere in the organization an official will have to be thinking ahead and devising ways and means of working, and if he is also engaged on other matters, such as the actual production, it is doubtful if either of his activities will be carried on with full efficiency. Similarly, as regards the vital subject of records, their compilation has to be accomplished by some means or other, however intermittently and inadequately, so that it is only reasonable to assume that a special official or department will ensure this work being done more efficiently and with greater value to the executives.

The test of the economic necessity of a planning department is whether the management is overburdened. Of course, the old management claimed to be omniscient, but there is no need to emphasize that the mental labour of

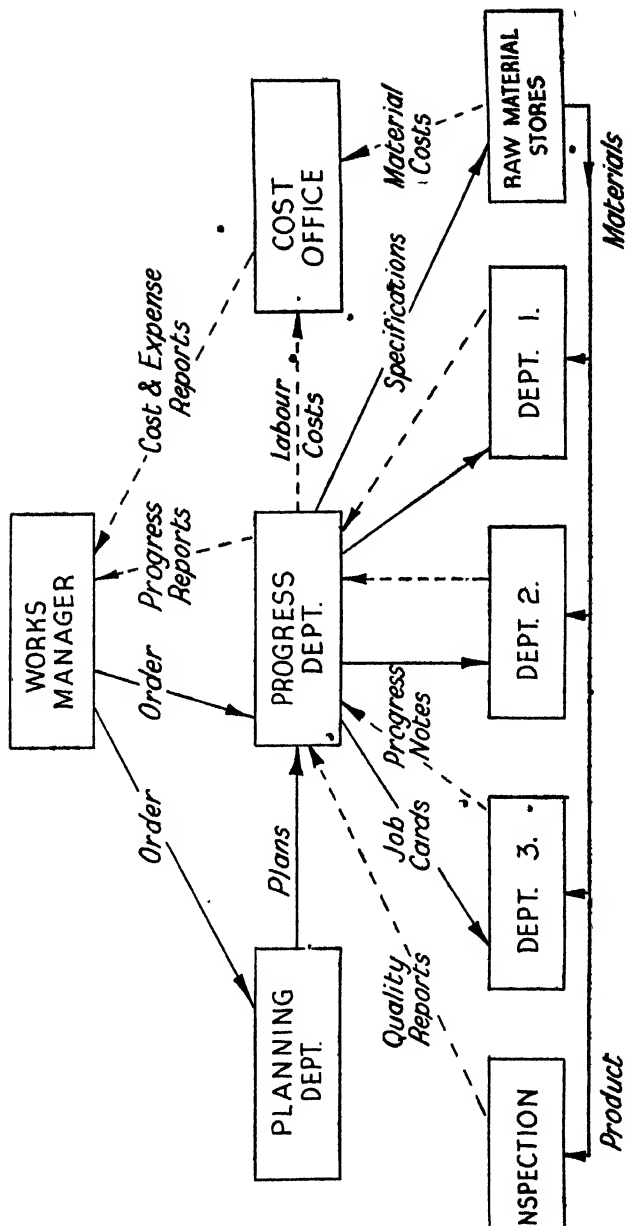


FIG. 2. WORKS ORGANIZATION INVOLVING PLANNING AND PROGRESS WORK

production is greatly reduced by planning systematically how, when, and where the processes shall be carried on.

A good test of organization arises in the case of the introduction of a new design in mass production. After the design has been settled and the drawings made, the planning department states the machines required, the grades of labour, the operation and assembly times, and so on. The jig and tool room has to prepare the necessary jigs and tools and see that they function properly. The rate fixers have to estimate the prices, the employment department has to supply sufficient labour of the correct grade, the machine tool repair department has to ensure that the machines are in working order, the purchasing department has to obtain delivery of the requisite supplies, and the inspection department to check them. These and many other activities have to be co-ordinated, so that work can commence at a fixed time without check or delay in the operation of the shops.

It may be contended that planning on the lines suggested is not characteristic of British engineering industry, but it is treated here to emphasize the fact that efficiency and economy of production and competitive power lie in thinking ahead, and not after production has started, or, worse still, when difficulties arise. It is essential to ensure that the manager is actually managing, the machinist machining, the designer designing, and so on, and not doing someone else's job or waiting for work to come to him; otherwise costs of production will be considerably higher than they should be, and quotations badly out in competitive markets.

A planning department increases the clerical overhead but decreases the shop overhead expenses, and has the additional advantage of stimulating greater production without undue speeding, by taking care of the needs of production before they arise.

The planning department is equally essential whether products are being made to separate orders, in which case

it makes the special studies required, or whether mass production is in progress when it makes out the schedules of work. In a large concern it is necessary to sectionalize the planning department, and separate officials will handle the analysis of orders, job standardization, rate fixing, routing of work, the preparation of work schedules, supervision of materials handling and transport, analysing and checking costs, and so on.

Planning, however, must not be carried too far, or it will have a dehumanizing effect on industry and defeat its own ends. It has to be adapted to the particular product being manufactured; whilst a system which has proved successful and efficient elsewhere may be used as a basis, each plant will have to solve its own problem by superimposing modifications to meet its special circumstances. The system must be dependable and keep close to practical shop conditions to prevent it becoming theoretical or arbitrary.

THE PROGRESS DEPARTMENT

It is one thing to plan and another thing to carry out. The advantages of planning may be lost unless the system of organization includes a means of ensuring that instructions are being carried out and that costs are being kept within prescribed limits. The function of the progress department is to see that production is carried out on time. It is concerned with moving as distinct from making. The work going through the factory is under the department's supervision from the receipt of an order till its dispatch. The department maintains a uniform flow of work in accordance with the schedule arranged, concentrating its attention on factors which may introduce delay. The first duty of the progress department is to see that supplies are available at the time the work is scheduled to commence. Parallel lines of work must then be synchronized so that no hold-ups occur due to delay of any part, and assembly work is made continuous. Any causes of delayed, or unbalanced processes are reported to the planning

department in order to provide greater productive capacity at the points in question. The progress department carries a heavy responsibility, viz. to see that the commitments of the firm are duly met, and that each section of the works is fully employed. It must be in a position to show at any time the divergence between the budgeted and actual production, and indicate to the higher control where the weakness causing any shortage lies. It is obvious that the progress department cannot effectively perform its function unless the manager has the status and authority of a senior executive. Without this, progress work becomes mere chasing. The relation between the planning and the progress departments is one of co-operation and mutual assistance. The former procures the right conditions for the progress department to work under, and the latter can only get the best out of what is available. If the aims of either are not being achieved it will turn to the other for assistance. The progress department must not be unwieldy, or it will become unprofitable. Efficiently organized, there will be no fear of this, but the department will be of vital assistance in administration of the works organization.

WHAT IS GOOD ORGANIZATION?

Can good organization be defined? Perhaps not in so many words, but it is not difficult to say what it does, and judge it from the results produced. The vital importance of the subject is indicated by the references to firms which have not done well, being in process of reorganization. Organization is something more than subdivision. Subdivision of labour is good, for it tends to increase output and improve quality, but it only yields increasing returns up to a point, and careful judgment must be exercised in determining how far specialization is to be carried.

Organization is something more than system. Systems are of the utmost utility, but will not work themselves. Methods will not run a business. The directors have to run

it and the staff has to be built up into a team imbued with co-operation in which initiative and elasticity are preserved. We must guard against overvaluing organization and undervaluing personality. The fundamental of control is to demand results and leave the subordinate to achieve them as he thinks best. Elasticity and initiative must be preserved, for it is almost impossible to foresee everything that ought to be done. To give too detailed instructions kills initiative, as the subordinate can say that obviously this or that ought to have been done, but it was not in the orders given. Devolution encourages decision and self-reliance. Impulses for action must well up from below. Good organization facilitates control of production and enables the work to be fitted into the departments and progress smoothly through the plant without congestion or delay or friction between the staff.

In the factory, organization increases the productive capacity of the plant by ensuring continuity of process and elimination of idle time. The work passes through the stages of production with no unnecessary handling. Organization results in smaller amounts of work in progress and a smaller stock of raw materials, and gives a greater security in fulfilling orders. It should be remembered that it is detrimental to goodwill to have to wait beyond the promised delivery. Good organization increases the output of saleable goods, decreases the costs of production and distribution, and makes economic mass production possible; in other words, organization enables the executive to obtain the utmost value from the investment in buildings, plant, and tools. It is capable of accommodating itself to unexpected demands, such as an urgent request for speeding up in special cases, i.e. it does not break down under stress.

A good organization is not impaired by the absence of particular individuals. If the return of an official has to be awaited before certain work can be started or resumed, the organization is defective. In a well-organized works

there is no hesitation in carrying on in the absence of individual members of the staff, as it will have been laid down who will deputize in such an eventuality. This opens up the important question of training men for future direction. There is a well-understood, because very human, disposition or rather temptation for officials to withhold a greater or less proportion of the functioning of their position from their assistants. It is not too much to say they definitely hope that in their absence trouble and difficulty will be encountered, and their value to the enterprise then be more highly estimated. However, the highly placed executive who said he was going for a holiday because the concern got on as well without him as with him was without doubt a true organizer. His statement was not quite correct, because there were matters on which only he could give a decision, but they were such that he could do this just as well on a golf course as seated at a desk. If every one in the firm had not known his job and the questions which had to be referred to the executive for his yea or nay had not been clearly defined, the latter would have had to be in his office grappling with questions which a subordinate could have dealt with. An enterprise does not run itself, but a well-organized one almost seems to do so.

The basic principle of organization is co-operation. It facilitates executive control, and the achievement of policies.

In addition to the use of charts, control is aided by records and reports, but a paper-work system must not be carried too far. For example, standard procedure instructions have their place in both shop and office routine, but the acid test of organization comes in dealing with matters for which there is no precedent.

The fundamentals of organization, then, consist in the provision for the automatic initiation of action, the establishment of appropriate rules and regulations relating to production, the automatic supply of reports from

subordinates, and the development of an adequate system to eliminate waste of time and effort. Everyone in the works should know his relative duties and handle routine matters without direction from above.

It must be remembered that any process of organization is deliberately making grooves, and, therefore, the grooves must not be cast-iron ones, but capable of being improved by methods which experience elsewhere has proved to be successful.

Attention given to organization really represents recognition by the management of the necessity for exploiting the resources of the factory to the fullest extent with a view to getting the utmost return for their expenditure.

When reorganization is necessary it usually requires a bold policy for satisfactory results, as changes are opposed by foremen, heads of departments, and others affected, but the issue of the economic functioning of the plant as a whole is too great to allow individual opinions or preferences to interfere.

In all matters concerning organization the co-operation of the accountant is necessary, as he will criticize any changes from the cost accounting point of view. The financial aspect of the enterprise is of over-riding importance.

Organization to-day is not only a power but a necessity. The more closely knit an industrial unit is, the greater its efficiency and competitive strength.

The Industrial Reorganization (Enabling) Bill had for its objects provision for the self-government of industries by enabling the majority of producers in an industry, notwithstanding the opposition of a small minority, and the introduction and enforcement of schemes for the reorganization of the whole or part of that industry with the general object of promoting greater efficiency, eliminating wasteful competition, and of facilitating the production, manufacture, and supply of the products of the industry.

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CHAPTER II

PERSONNEL POLICY AND WAGES PAYMENT

MANAGEMENT OF STAFF

PERSONNEL administration is concerned with the improvement of human efficiency as distinct from mechanical and material efficiency. There is no clear line dividing personnel from production problems, but in the onrush of mechanical progress the tendency was for industry to concern itself with making things and to forget the workers and their human needs.

A prerequisite of efficient management is a knowledge of the human factor and an understanding of the handling of human beings. There can be no doubt as to the economic advantage of the study of personnel. It may be asked why cannot the engineer pick up personnel methods as he goes along with his work, but a little consideration will show that theory before practice is more valuable than theory during or after practice. Nothing is more important in fostering good industrial relations than an intelligent and progressive personnel policy.

EVOLUTION OF HIRING AND "FIRING"

The changing character of industry is well illustrated by the evolution of methods of hiring and "firing." This is obvious on comparison of the old-fashioned methods, e.g. at the docks, with those of a modern employment department which is open at all times and under the supervision of a manager appointed for his human sympathies.

Before considering modern employment methods, emphasis must be placed on the fundamental importance of the personality of the personnel manager. He must possess, tact, good sense, intuition, courtesy and optimism. System

is not enough; the first contact of recruits with the firm must be right or relations may never be right. Labour administration is always difficult and requires ability of the highest order.

In the past, the works manager or the foremen appointed as well as controlled the workers, but when works grew too big for this method of appointment, the officials concerned being too busy with production, personal contact was lost and in large concerns the personnel department takes the place of personal knowledge of the workers.

AID TO PRODUCTION

The personnel department is primarily an aid to production. Its first duty is to provide labour in the quantity and of the quality desired by the works manager. The personnel manager must be conversant with all possible sources of supply, with a view to selecting the best obtainable. Haphazard and empirical selection of employees has gone for ever, and is being replaced by scientific interviewing and selection for vocational fitness by medical, psychological, and mechanical tests.

LABOUR TURNOVER

One of the duties of the employment department is to maintain labour turnover at a minimum. With a high turnover the cost to the firm is serious, as practically every employee has to be trained even if allegedly skilled, whereas the expense of training young or new employees may amount to £25 each or even more. By inquiry into the causes of labour turnover the employment manager may be able to effect reductions and thus assist in the stabilization of production.

Analysis of the turnover will indicate whether the cause lies with the employee or the management. If a worker is lazy, incompetent or insubordinate, it is obviously to the benefit of the firm that he should leave, but if turnover is due to bad wages or conditions, hazardous shops, or unjust

or incompetent management of whatever grade, it is the duty of the employment officer to bring the facts to the attention of the higher control. In the old days it was impossible for reasons of dissatisfaction to be brought out, but with a modern personnel department employing scientific selection and guidance, fitting the worker to the job, supervising education and apprenticeship, and exerting a steadying influence on discipline and disputes, there is a greater opportunity of establishing and maintaining good relations, unmarred by individual slips from the tenets of good management.

EDUCATION AND TRAINING

Management has not only to select and place, but to train, promote and encourage employees. Various schemes of education of industrial employees are available in conjunction with the local education authorities. Some large firms have apprenticeship schools of their own, others have schools of instruction in specific jobs. The whole subject of increasing the individual proficiency and productivity of the works employees, including the foremen, comes under the purview of the employment officer.

Training is frequently limited to consideration of training for a job, whereas it should be extended to include training on a job, not only because production methods are evolving rapidly, but because each employee should be engaged on the highest class of work of which he is capable. Educational facilities should be provided and linked up with the firm's promotional scheme, and their use encouraged.

PROMOTION

As regards encouragement, nothing—including even in some cases the financial inducement—stimulates like appreciation and conveying to the employee he is doing useful work. For this reason, promotion should be given to men of proved ability and loyalty whenever practicable.

It is assumed, of course, that the employment officer's knowledge of sources of supply include the existing organization. It is very discouraging to the work force if an undue proportion of appointments go to newcomers. The employment officer should draw up promotion plans of which the best known are the three-position plan in which everyone is considered as an understudy and a teacher, and the multi-chain plan embodying alternative directions of promotion. Next to good wages, stability of employment makes a good job in the eyes of operatives, and the personnel manager can add appreciably to regularization of employment by arranging transfer of labour, with dismissal from the firm's employ as the last resort.

JOB SPECIFICATIONS AND MAN SPECIFICATIONS

One of the objects of the employment department is to ensure efficient and economical investment in man-power. To this end some firms determine the essential factors in a specific kind of work and with this analysis before them endeavour to fit into the job workers having the requisite qualifications for its efficient performance. In practice, job specification cards are drawn up stating the work to be performed, the knowledge of equipment and tools necessary, the physical characteristics or skill qualifications required, the hours, method and rate of pay, the wage increase or promotion possible, whether training courses are necessary and, if so, the type and length, and so on.

After engagement the system may be followed up by a personnel rating scheme by which the employees are periodically rated or valued so as to see that each is not only doing the type of work for which he is fitted but the best work within his capability. The scheme facilitates standardization of wage levels throughout the works, introduces uniformity in wage rate advances and proves a great help in promotional plans. Ability is not overlooked, but outstanding men are advanced in graded progression.

RECORDS

It is evident that the employment manager has to keep a large number of records, in fact the department is largely a recording office. When help is required in the works a request should be made on a form giving as far as practicable the job specification. All applicants have to fill up an application for employment form, stating their training and experience. The department keeps an employment record of each employee giving the result of medical and psychological examinations and particulars of the operative's progress with the firm, the manager's rating of the man and reasons for promotion, leaving and so on.

Health and Unemployment Insurance records are kept in the department.

With a view to envisaging the position of the working force at a glance, the manager will chart the key factors, such as numbers employed, turnover, sickness and absenteeism and accident rate and severity. He will, of course, use his data as a means of research to the benefit of the employees and the firm. He will carry out a labour audit and issue a review or report at regular intervals.

CONDITIONS OF WORK

Personnel management is greatly concerned with the conditions of employment in the factory. Under this heading come health and hygiene, accident prevention and relief, ventilation and lighting, lavatory and washing facilities, heating, noise prevention, rest periods and, in fact, all conditions relating to material and physical welfare.

It is evident that the employment manager must have an expert knowledge of factory legislation and the regulations of local authorities, though he will consider these requirements only as a minimum, and, in fact, the provisions of most firms far exceed the legal minima.

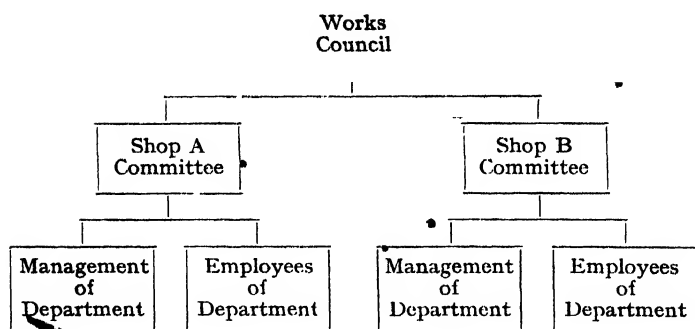
EMPLOYEES' WELFARE SERVICES

Employees' welfare services under the care of the labour manager include the works canteen, medical and dental supervision, recreation and social activities, libraries and clubs, the works magazine, industrial thrift plans, pension schemes, housing and other financial assistance schemes, for employees.

ROLE IN INDUSTRIAL RELATIONS

The purpose of the employment department is to ensure systematic and proper attention to all matters relating to the labour force with a view to establishing and maintaining successful industrial relations. Recognition is given to the fact that workmen and women differ widely in desires, impulses and attitudes and must be handled with thoughtful care and treatment, justice and fair play, which is not inconsistent, however, with uniformity of policy throughout the organization. The manager will take long-range views for the development of employees as individuals as well as efficient workers.

In addition to engagement of labour, conditions of work and security of employment (as far as practicable), he is concerned to some extent with hours and wages. With regard to the former he will see that they are reasonable apart from legal requirements, with restricted use of overtime, and he will co-operate in time study and the adoption of the most effective type of wage incentive. The manager will, of course, be fully conversant with the Truck Acts and Trade Union or Trade Board regulations. He plays an important role in the organization of management-employee relationships, not as representative of the employees but in a consultative capacity. In practice he serves as secretary of the committees and council which constitute the structure of joint relationships or co-operative dealings in the firm. This may be organized as follows—



The committees envisaged are : Safety, Health and Working Conditions, Education and Recreation, Avoidance of Waste, Thrift, Insurance and Pensions, Efficiency, including suggestion schemes and financial incentives and, perhaps, Discipline, Grievances, and Hours and Wages. Proper means must be established for carrying out the committees' decisions. In this way, in so far as representative government is practicable in industry, the employment manager ensures the successful working of industrial democracy.

In relation to trade unions the employment manager will recognize and work with them, insisting on loyalty in adherence to agreements, and remembering that most of their ideals are noble and their conceptions right, as, for example, their great pioneering work in voluntary schemes against unemployment and sickness. Welfare work is not intended to undermine the solidarity of labour, but to promote loyalty instead of hostility and engender a real corporateness and joint sharing in material prosperity.

INDUSTRIAL PSYCHOLOGY

Reference has been made to the use of psychological tests in the selection of labour to distinguish those who do and those who do not possess qualifications and aptitudes necessary for a particular kind of work. Discussion of the methods, types and validity of such tests would take us

too far afield, but their success depends on the way they are used as well as on their merits. This is, however, only one direction in which the psychologist can help the industrial world, and the work of the Industrial Health Research Board and the National Institute of Industrial Psychology must be studied fully to appreciate the contribution of the psychologist to industrial efficiency at reduced human cost. Not only does he endeavour to assure that the workman is doing the work for which he is best fitted by his aptitudes and abilities, but also under conditions eliminating wasted effort and needless irritation and fatigue and in an atmosphere of understanding and goodwill.

The study of the effect of the factory environment on the bodily and mental health of the worker has proved a rich field for securing optimum results as regards both output and the economical use of human energy.

Considerable light has been thrown on fatigue, monotony and accident proneness by the psychologist with ensuing reduction of accidents, sickness, labour turnover and spoiled work, and an increase in output, efficiency and happiness of the workers.

The labour manager will be conversant with the psychological limitations of a man as a working unit and will employ as necessary the experts to adjust the machinery and conditions of labour to the operatives' capacities, remembering above all that mental causes are basic in amicable industrial relations, and industrial efficiency is dependent on contentment. He will organize the Safety First movement in the works in the light of the fact that the majority of accidents are caused by failure in the human factor.

THE SPECIAL POSITION OF FOREMEN

The evolution of industrial organization has developed the foreman's position from that of leading craftsman to that of supervisor of his department's activities. It remains

none the less a key position. He is, in fact, to be compared to a non-commissioned officer, responsible for the smooth running of his section. However much planning has been accomplished, the foreman is responsible for obtaining results. His job is co-ordination in the workshop with due regard to the relative importance of all factors in efficient production. He must be capable of analysing the work in order to have all parts of the equipment continually active and a steady flow of work through the department maintained. He must co-operate with the stores department as regards materials, the machine-tool department as regards tools, and with the plant engineer. He must be able and willing to teach and to co-operate with the training department, if there is one. He must inform the progress department if difficulties occur which may cause delay in delivery, and must advise the management if their instructions seem likely to produce results which they apparently had not foreseen. The foreman must also do his best to assist the cost office by ensuring accuracy of records, as regards not only materials and labour, but also indirect charges.

The foremen play an important role in the efficient control of their departments. It must be remembered, however, that under scientific management, before they begin to exercise their function, the department has been planned, the sequence of processes laid down, the operation rates fixed, and the standard of workmanship required has been determined. The foremen are responsible for maintaining the required rate of production of the specified quality and at the minimum cost. They must have a knowledge of many branches of work which do not fall within their responsibility in order to secure co-operation between their departments and the whole organization.

The importance of the foremen lies in the fact that they are responsible for the immediate management of men. They must lead and inspire, not drive and dismiss. They are in intimate contact with the workers and interpret the

firm's plans to them and, conversely, the workers' views to the management. If labour's first contact with executive authority is not on a satisfactory basis, difficulty is likely to arise in carrying out the management's plans. The comparative failure of scientific management in many American plants has frequently been attributed to the tyranny of the functional foremen. The importance of the careful selection of foremen and training them in the leadership of men, whatever type of organization is adopted, needs no emphasis. Nor must the contributions which they are able to make to the stock of managerial knowledge and successful operation of the enterprise be overlooked.

By encouraging suggestions and displaying scrupulous fairness, they may be able to utilize the latent capacity of the workmen and effect improvements of considerable value to the enterprise. The day-to-day experience of the foremen must be made available to the management. Opportunities should be made to learn their views, and on works committees their abilities and services can often be utilized with advantage. Properly handled, they can render great assistance in propagating and maintaining the proper spirit of organization and creating the right atmosphere in the shop by disseminating loyalty, sense of duty, and enthusiasm throughout the working force. Personality and leadership constitute a very important aspect of a foreman's qualifications. To possess the ability to handle men combined with practical knowledge is by no means common; it requires a character which inspires confidence and trust, and it is considered that this should constitute a primary requisite in choosing foremen.

The foreman also holds a key position in making safety work successful. The responsibility for training apprentices and educating the workmen may also rest upon him, and he should continually plan to keep every man enthusiastic as a means of maintaining the efficiency of the department.

WAGES AND INCENTIVES

DIVISION OF LABOUR

We saw in Book I that the era of subsistence husbandry was succeeded by a period in which the employment of the community was specialized into single trades. Later on industries were split up into a large number of separate operations. This process is called the division of labour. Although Adam Smith wrote before the Industrial Revolution, he fully appreciated the true meaning and importance of what is involved in this principle. He showed that specialization is fundamental in the economic organization of industry in that the productive power of labour is thereby increased. The subdivision of processes leads to greater efficiency of the workers, the improvement of tools and the invention and application of machinery. The use of machinery leads to further specialization of labour, so that the effect is cumulative. Every useful discovery and invention has been applied or become operative through the utilization of specialized knowledge and skill, and every increase in such specialization renders possible the further exploitation of such inventions, and facilitates new ones. The history of civilization is the history of the extension of the principle of division of labour. A limit to division of labour is set only by the extent of the market, which determines the scale of production. We may summarize the division of labour into four main forms: between one occupation and another, between one process and another, between one function and another, and between one district and another—in industrial communities districts become specialized like individuals.

ADVANTAGES AND DISADVANTAGES OF SPECIALIZATION

The disadvantages of specialization should not be overlooked. Among them is monotony of labour, which robs the workman of all-round development, compared with

the old craftsman. Intensity takes the place of extensity. It is suggested that specialization gives the workers no opportunity to develop initiative and judgment, and leads to concentration of the masses in factories and to excessive competition between workpeople. Industrial organization becomes over-sensitive, and frequent unemployment results. The workman is used as a means to an end, and labour becomes a mere commodity. On the whole, there is no doubt, however, that the advantages of specialization preponderate. We have remarked on the economy in production which it effects. As regards its effect on workpeople, it lessens the time in learning a trade, leads to increased dexterity, and better permits the utilization of aptitudes. Machinery takes over the monotonous work, increases the demand for general intelligence and adaptability, and weakens the barriers between trades, i.e. increases mobility of labour. Factory life stimulates mental activity, and depressing industrial conditions are not inherent. There is a modern tendency to decentralization, and factories are being increasingly erected in rural surroundings. Specialization induces a local market for skill, and specialized machinery leads to continuity of employment. With the progress of specialization the conditions of the workers have steadily improved also. Specialization is still increasing in certain directions—for example, in buying, advertising, and management—owing to the economies induced, but, as remarked above, it has its practical limits, just as large-scale production has. On the production side, specialization has led to standardization and interchangeability of parts, so that erection, assemblage, completion, or repair of even complicated machinery can be carried out with facility at great distances from the production centre.

COMPENSATION OF LABOUR

The subject of wages is one of the most difficult and controversial in the whole range of economics. Its vitally

practical importance leads to partisanship and passionate views.

It may be noted that there is really no such thing as a general rate of wages, but if money wages rise and the prices of workmen's commodities do not, there is said to be a rise in the general rate. In other words, the smaller the proportion of wages spent on food the greater the prosperity. On the whole there has been a considerable rise in the general rate of wages in the last hundred years, and at about the same rate in the United Kingdom, United States, and France.

Wages are the nominal or money payment for the work performed. Real wages refer to the value of the wages expressed in terms of things in general, i.e. of the goods and services which they will procure. We may note the anomaly that real wages are higher during business recession than during prosperity, but real earnings, i.e. wages paid over a period of time, are probably lower owing to the amount of short time worked. Money wages give no indication of the relative economic welfare of wage earners at different times. To ascertain this it is necessary to translate money wages into real wages from a knowledge of the changes in the level of prices. For the purpose in view we must use the retail prices of goods entering into working-class consumption, and not wholesale prices. Variations in the working-class cost of living are given by the Ministry of Labour Index Number. (See Book I, page 125.)

BASIC FEATURES OF WAGES

Year by year the activities of the productive forces produce the social dividend out of which all claims have to be met. These claims are made up of the four categories of distributable income—rent, interest, profits, and wages. The problem of distribution is concerned with determining the principles underlying the apportionment of the social dividend among these categories of income.

The iron or brazen "law" of wages, as it is called, was to

the effect that as population tends to increase faster than the means of subsistence, wages are never for long more than sufficient to provide the necessities of life for a labourer and his family. The demand for labour follows an economic law, but the supply of labourers does not. The supply of labourers will not, however, be increased if the standard of comfort falls below a traditional value. When Ricardo expounded this subsistence theory of wages, however, he had no idea of the greater productivity that would arise from science and invention.

Another theory of historical interest is the wages fund theory, which largely influenced the judgment of early economists. It supposed that a certain amount of capital was devoted unconditionally to the payment of labour, the fund being distributed under competition between the workmen, who must work independently of the rate of wages. Unfortunately, facts are against the theory, as they have shown that there may be high wages in a new country with a rising population, and low wages in an old country with large accumulations of capital.

The effect of the invention of machinery on wages may be considered. Its sudden adoption will cause hardship and probably a fall in wages of the labourers whose knowledge only of the old processes cause them to be supplanted. Subsequently, however, owing to the extended market and the greater skill required from labour, the wages of the machine tenders may rise.

The productivity theory of wages conceives that they are paid out of a continuous stream of circulating productive capital, and depend not only on the efficiency or productivity of labour but on all factors which increase the real national income. The distribution of the flow of wealth depends on the relative strengths of the bargaining parties. It will be realized that capital and labour have a reciprocal demand for each other's service, but there are obviously limits to the prices at which these services will be forthcoming, the terms being determined by the combinations

on either side. Employers realize, of course, that low-paid labour is generally expensive on account of its inefficiency.

Wages are fixed by economic force, not economic justice, and consideration shows that wage rates are largely a reflex of demand for and supply of labour. The demand for labour is indirect and largely dependent on present profits and also prospective profits. The demand price is the marginal worth of labour to the employers, and depends on its marginal productivity. It should be remembered that the law of substitution is always at work, i.e. the employer will replace labour by machinery whenever it is more remunerative to do so. The supply price of labour is the wages at which different quantities of labour are forthcoming, and, of course, is connected, if only remotely, with the cost of rearing, training, and keeping workpeople. It would, perhaps, be more correct to say that wages vary between a maximum of the net value of the work to the employer and a minimum which is the least an employee can take to maintain his habitual standard of living. As we have seen, the standard of living plays an important part in the settlement of wages. This accounts for the greater efforts exerted in opposing a fall in wages than in endeavouring to obtain a rise. The quantity of labour employed in any industry is seen to be that of which the supply price and the marginal worth to the employers are identical.

The true theory of wages appears to include elements of both the subsistence and the productivity theory. In addition to depending on the efficiency of labour, wages also depend on the efficiency, or, rather, marginal ability, of the employers. The invention of machinery and the saving of capital increase the national dividend, and to that extent tend to raise wages.

PRIMARY PAY SYSTEMS

There are several methods of wage payments, the system adopted being dependent on the nature of the industry

concerned. For the payment of basic wages time rates or piece rates are employed or a combination of both.

Under time rates the workman is paid so much per hour, day or week, the quantity of output having little or no bearing on the rates. They are generally paid where the employment is continuous, where the quality of work is of fundamental importance, or where the work cannot be standardized, as in transport, distribution and agriculture. Careful supervision is usually necessary. Pay-roll compilation is simple, but time rates contain no inspiration, and are specially irksome to a good workman if there are no annual rises. The simplicity of determining wages in advance is a point of favour with trade unions, and it is the only satisfactory method where the work does not admit of quantitative evaluation. It is estimated that over 50 per cent of industrial workers are on time work.

Under piece rates a fixed sum is paid per piece of work or unit of output, regardless of the variation in time taken, but usually with a strict regard to previously established day rates. They reduce the cost of supervision and to this extent overhead expenses. They simplify costing and are better from a cost accounting point of view. First-class workers usually like piece rates, provided there is no price cutting or undue speeding-up and overstrain. It is sometimes advanced that piece rates tend to increase quantity only at the expense of quality, that the workman is induced to rush, and that the standard of craftsmanship is lowered. With highly mechanized production, however, the workman has not a great deal of control over quality, and a proper system of inspection can readily take care of the maintenance of a proper standard. The difficulty of setting and revising fundamental piece rates is often of a high order, but by an enlightened understanding between management and workers this may be overcome. From a labour point of view objections have been advanced that piece rates tend to produce unemployment by heightened production in an inelastic market, and that they break up the solidarity

of workers, but, generally speaking, trade unions are not opposed to payment by results where a satisfactory standard of measurement can be found. Group piece rates are often of high practical importance, and refer to the system of paying a fixed sum to a group of men on the completion of an assigned task.

In some cases a collective bonus is the only possible alternative to pure time work, the bonus being usually allocated in proportion to the men's basic rate of pay. It is advisable to limit the groups to operators whose work is related. The efficiency of corporate effort depends, of course, on the skill of the management, and, moreover, if a group is made too wide it may well be that the increased production for which the bonus is being paid arises from the efforts of a relatively small portion of the group. Nevertheless, the risk is sometimes taken, and in order to stimulate collective effort, a bonus may be paid to all the employees if the total output of the works exceeds a standard amount. The stimulus given by payment by individual results is, however, usually more effective in increasing efficiency.

Another method of payment is sliding-scale wages, an arrangement for regulating wages according to the market price of the commodity or the profitableness of the industry. Such a system has operated in coal and the iron and steel industries, and has the advantage that the wage variations are automatic instead of involving lengthy negotiations and, perhaps, strikes. Selling prices are, however, an inadequate test of economic conditions as they do not allow for changes in the cost of production or in the volume of trade.

The remuneration of most workers is governed by both time and piece work factors. Most systems have a framework of time-rate considerations, including the various incentive wage systems involving the payment of a premium or bonus. Piece wages and bonus systems must be based on time and motion study, which is considered in a later

chapter. Incentives which, though not a part of the wage system, have been devised to give the workers a financial interest in increased productivity include profit sharing and co-partnership and will be considered below. It is, of course, deplorable that the majority of workmen have no interest in the industries of the country beyond the wage they receive. Particularly since the rise of joint-stock companies, personal contact between employers and employed has tended to disappear. The employers are, of course, the shareholders, who often have no knowledge of or contact with the industry whatever, and are mostly concerned with the dividends earned.

The distribution of wages between one occupation and another depends fundamentally on competition, but the competition is not free or open, due to differences which are inherent in some cases, to lack of educational opportunities in others, to conservatism, to imperfect mobility of labour, and to artificial restrictions imposed by trade unions or professional and other bodies.

INCENTIVES

It seems only logical to relate wages to the amount and quality of the work performed. The main difficulty lies in measuring the services of the workman. All incentive systems depend on time studies and, if we suppose standard times or standard rates to have been established, then the choice lies between piece work and its variants and premium-bonus systems.

If a workman saves time on the standard set, to whom does the value of it belong?

Under time work, labour gains nothing, though the labour costs and overhead costs are lowered.

Under piece work, labour gains all the time saved and labour costs remain constant, though overheads are reduced.

Under premium-bonus systems, the firm and the workman share the time saved, and both labour cost and overhead costs are lowered.

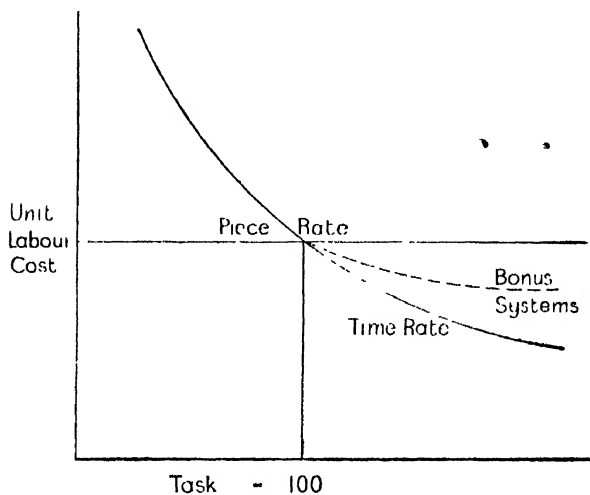
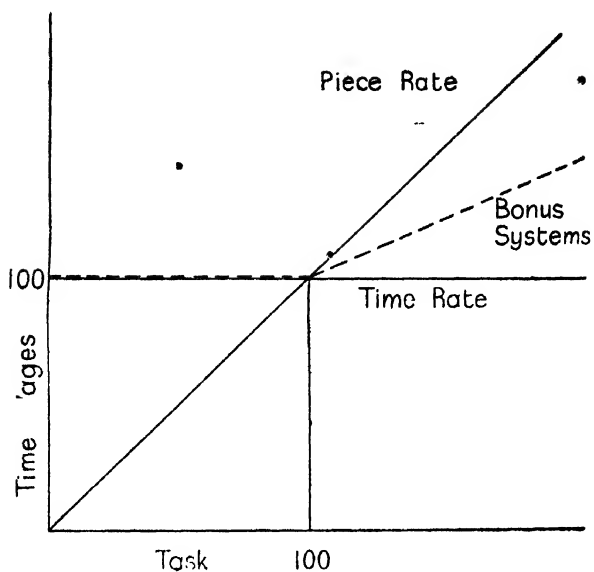


FIG. 3. VARIATION IN WAGES AND LABOUR COST WITH INCREASED OUTPUT

Fig. 3 shows the daily wages and the labour cost in relation to daily production under the three systems.*

Under piece work the employer has little or no incentive to provide facilities and improve conditions except in so

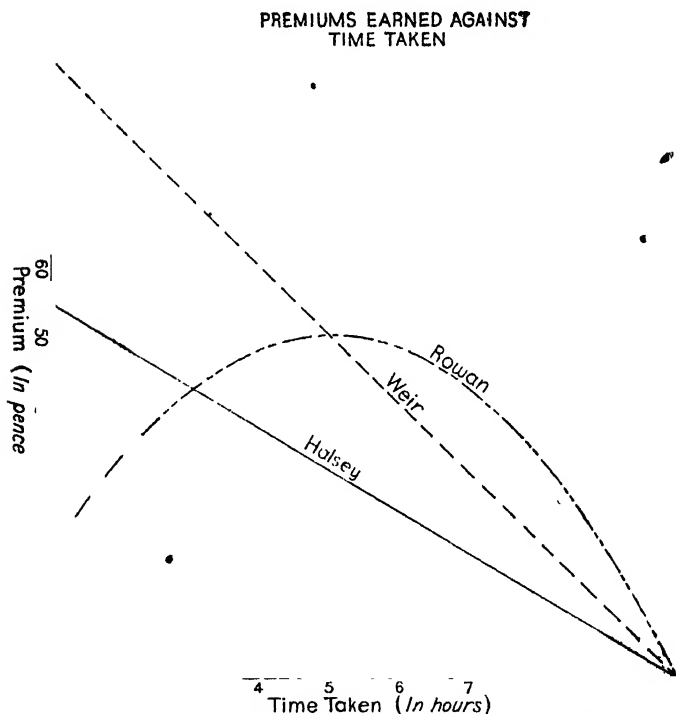


FIG. 4. PREMIUMS EARNED UNDER BRITISH SYSTEMS

far as overhead costs are lowered. The determination of standard times is important. It is always possible to make a mistake in setting piece rates and difficult to correct it

* The total factory cost per unit decreases under all three systems, but above task level faster under day rates than under the piece system, with bonus systems intermediate. A system of wage payment is, of course, conceivable under which the labour cost increases per unit and the total unit cost remains constant.

owing to the bad effect of rate cutting, but under a bonus system mistakes are less onerous and less costly. With new work it is advisable to establish temporary piece rates subject to revision or cancellation.

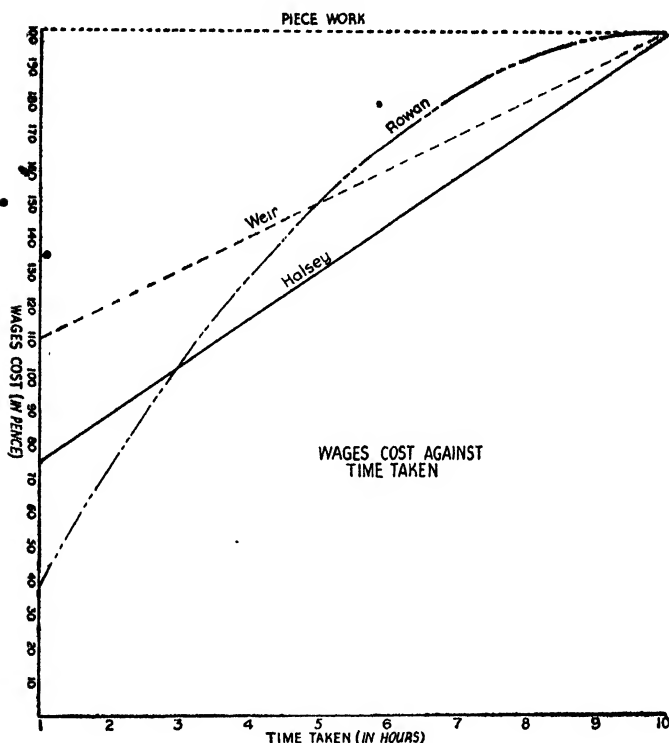


FIG. 5. LABOUR COST UNDER BRITISH PREMIUM SYSTEMS

A variant of piece-work payment is called the differential piece rate, being in fact the original Taylor system. A standard rate was set for the workmen achieving the task level with a much lower figure for those not working at this rate. It was intended to penalize the slow worker, and inefficient men were removed from the shop. Subsequently, an intermediate rate was introduced (85 per cent

of the task) and multiple piece rates, being flexible, serve the purpose of grading employees. The straight piece rate, in which the reward is in direct proportion to the effort,

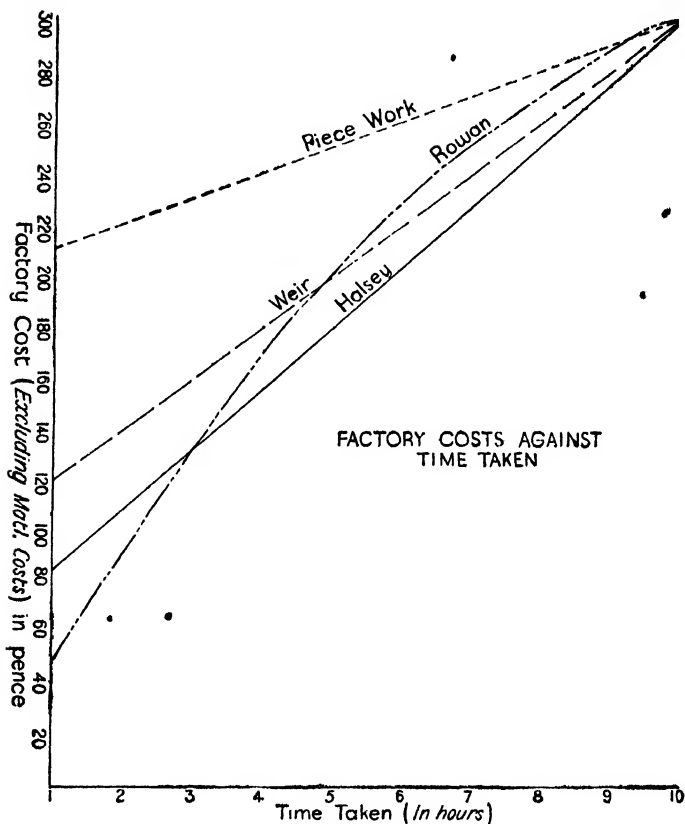


FIG. 6. FACTORY COSTS UNDER BRITISH PREMIUM SYSTEMS

has, however, many advocates who consider it the simplest and soundest method.

BRITISH PREMIUM METHODS

Of the various methods in which a fraction of the amount of time saved from the standard time is credited to the

workman we may distinguish as to whether the fraction is constant or variable. Under the Halsey and the Weir systems the fraction is one-third and a half respectively,

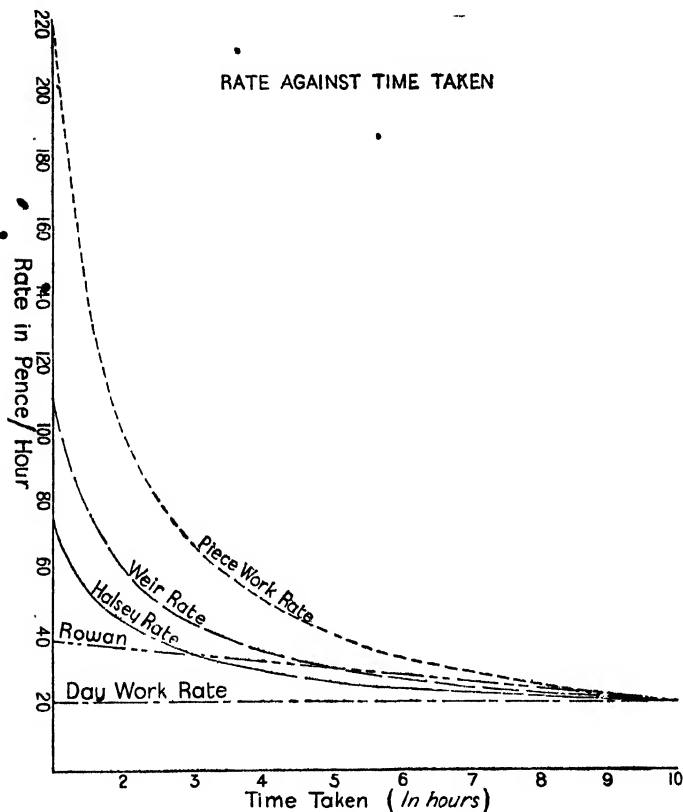


FIG. 7. WORKMAN'S RATE UNDER BRITISH WAGES SYSTEMS

and under the Rowan system it is the ratio of the time saved to the standard time.

Let H_s = the hours allowed or standard time

H_A = the time taken on a job

R_h = the workman's rate per hour

Then under the Halsey System the bonus equals

$$B = \frac{1}{3}(H_s - H_A)R_h$$

and the man's earnings equal

$$R_h \cdot H_A + \frac{1}{3}(H_s - H_A)R_h = \frac{R_h}{3}(H_s + 2H_A).$$

Under the Weir system, $B = \frac{1}{2}(H_s - H_A)$

$$\text{and earnings} = \frac{R_h}{2}(H_s + H_A),$$

Under the Rowan system

$$B = \left(\frac{H_s - H_A}{H_s} \cdot H_A \right) R_h$$

and earnings equal

$$R_h H_A + \left(\frac{H_s - H_A}{H_s} \cdot H_A \right) R_h = \frac{R_h}{H_s} \cdot H_A (2H_s - H_A).$$

The incentive from the Weir system is high if the standard times are generous. For small savings in time the Rowan system gives the larger bonus; when half the time is saved the two types of bonus are equal. When the time saved is greater than a half the Weir bonus is the greater.

Figs. 4 to 7 show a comparison of premiums, rates and costs under the three systems mentioned for a specific job rated at 10 hours for a workman at a standard rate of 1s. 8d. and an oncost of 10d. per hour.

AMERICAN BONUS SYSTEMS

The Gantt Task and Bonus Plan guaranteed an hourly rate up to the achievement of a standard task, but, if completed in the standard time, the hourly rate was increased 20 per cent. When the standard task was exceeded, a percentage of the time saved was paid to the worker in addition to the higher rate. The system was based on the idea that the sharp jump in rates at the task

point caused a workman to accomplish the standard every time. Under this scheme the foremen may be paid a bonus if a specified number of men earn a bonus.

The Emerson Efficiency Plan guaranteed a day wage and, having set a rather high task level, paid the workman a bonus based on his efficiency ratio measured by the ratio of the standard time to the time taken. At 66 per cent a small bonus was paid, increasing up to 20 per cent on the guaranteed rate at the task level. Above the task level the man was also given the time saved. The Emerson plan had the advantage of a gradual transition over day rates as efficiency increased from sub-standard to super-standard work.

Special difficulties may arise in connection with beginners under incentive plans. It is usually considered best to pay them an auxiliary sum at the start. Some plans have been devised with consideration for beginners specially in view such as the Barth Plan, in which the hourly rate paid was the square root of the ratio of the standard time to the actual time multiplied by the standard rate.

THE BEDAUX SYSTEM

The Bedaux Point Premium Plan, formulated in 1916, is the best-known of the gain-sharing plan based on the predetermination or standardization of the amount of work to be done in a time unit of a minute. For each job the amount of useful work performed by an average operator per minute, making due allowance for rest and delays (i.e. dependent on the nature of the effort), is called a B point or unit. It is the amount of work a normal operative will do in one minute at the normal speed under ordinary conditions, and 60 B's constitute an hour's task. The point standard for a job is the number of B's allowed for a given piece of work. The number of B's produced by each individual is posted per day, and the value of the number in excess of 60 per hour is shared by the direct and indirect labour. The worker concerned may get 75 per cent or even

90 per cent, the balance going to the indirect labour and supervisory force. It will be seen that the labour cost per piece is constant as in any piece-work rate plan, but the earnings are usually lower than under a piece rate owing to the high task set. With the usual nomenclature, it will be seen that the earnings of an employee are—

1. Up to the task set

$$R_h H_A$$

2. Above the task

$$R_h H_A + \frac{3}{4} R_h (H_s - H_A) = \frac{R_h}{4} (H_A + 3H_s)$$

Base rates are established on a job by time studies and depend on the skill, experience and responsibility involved, and the Bedaux premium is proportional to the effort exerted above the standard. Delays are reported in minutes and allowances are made as follows. If the department is responsible for the lost time, as in the case of machine stoppages or waiting for work or trouble with materials, the equivalent points are given to the employee and charged against the supervision bonus. If the lost time is due to the employee's fault he is not, of course, credited with the B points he might have performed. A checker makes out daily premium cards which are posted to a premium posting sheet showing each operator what his efficiency was on the previous day and the bonus earned. An analysis sheet shows the efficiency of the direct and indirect labour together with their cost and reasons for deviation from the standard. A weekly recapitulation sheet provides an overall index of general efficiency of the department on which supervision bonus is paid.

It will be seen that the plan involves an incentive to direct labour based on its efficiency and an incentive to indirect labour based on the productive work done, or the ratio of standard labour costs per point to actual labour cost per point.

The limitations of the Bedaux plan include the cost of time studies, checking and clerical work, the amount of inspection required, and the facts that it gives little or no thought to improvements in methods and does not control direct or indirect material costs.

The plan has more to recommend it as a means of strong managerial control than as an incentive wage system.

The Haynes Mani Premium Plan, first used in 1924, is another system based on the amount of work which should be performed in a minute as a unit, jobs being measured in standard man-minutes of work. Standards are established by time study, and a manit is four-fifths of the full amount of work a normal average workman can do in a minute throughout the day without over-exertion. The standard rate of production is 60 manits per hour and the normal rate usually about 75 manits per hour. At first the task level was set rather low, and of the time saved one half went to the employee, one-tenth to supervision, and four-tenths to the firm. When the system became more standardized five-sixths was given to the workman and one-sixth to the supervision. The employee's earnings (with the usual nomenclature) were therefore

$$E = (5H_s + H_A) R_h/6.$$

In a later plan the full saving was given to the direct producers and supervisors, and indirect labour was rewarded by $4\frac{1}{2}$ per cent on the combined earnings of direct labour, this, of course, coming from the savings in overheads from increased production.

Under this system no credit in manits was allowed for bad work. This plan is also a good production control system as it draws attention to production hold-ups such as waiting for work.

The accompanying diagram may be useful in indicating the inter-relation between time wages, piece wages and the various bonus systems. It can, of course, be suitably augmented to include the other premium plans.

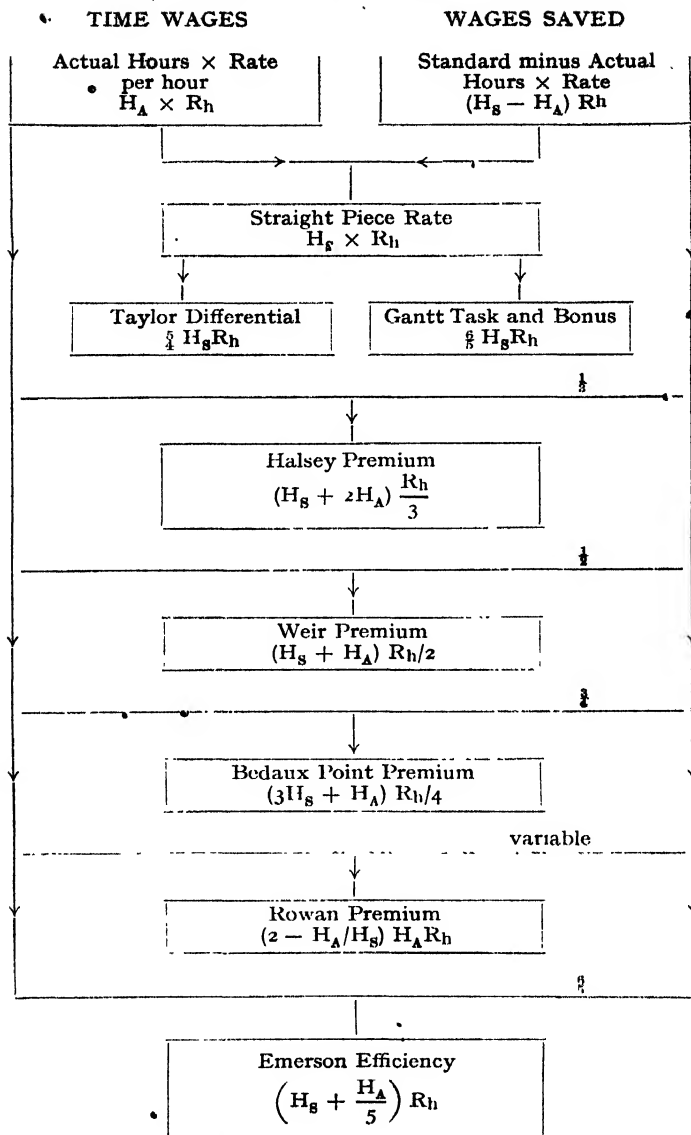


FIG. 8. DIAGRAM SHOWING INTERRELATION BETWEEN TIME, PIECE, AND BONUS SYSTEMS

GROUP INCENTIVES OR COLLECTIVE BONUS
PLANS

The aim of incentive plans is, of course, to increase production in unit time. Under individual systems the incentive is strong and immediate, but other measures are required to maintain quality and co-operation between employees. In continuous processes, production and assembly lines, or where the efforts of a number of workers are required to complete a part or job and it is not practicable to obtain the output of individuals, it is necessary to pay a group bonus if it is desired to retain the incentive payment idea. Wherever a process or organization is collective in character, a group bonus may be found advantageous. It will be seen that the idea might be extended to a whole shop or works, but it is usually not advisable to do this. The group must not be too large for the community of effort to be appreciated by each member. In other words, there must be belief by the individuals in the group idea and that the remuneration for extra effort is being shared justly and reasonably.

Whilst not so strong an incentive as when the emphasis is on individual performance, a group bonus constitutes a steady and persistent stimulus to organized effort. Community of interest engenders co-operation and team work; the skilled help beginners so that the amount of training and supervision is reduced. The working environment will be more pleasant, quality may improve, conscientiousness and alertness are promoted in reducing scrap and defective workmanship. Time-keeping, checking and costing are simplified, and a saving in clerical work may be effected.

The group basis stimulates co-operation and loyalty, but it must, of course, be backed up financially. Simplicity of understanding the scheme and confidence in the management are just as requisite for satisfactory working as in the individual systems discussed above. There must be no arbitrariness or suspicion. Disadvantages that have been suggested against group bonuses include the fact that there

is no check on individual efficiency and exceptional ability may be penalized. There may also be some difficulty in arranging payment for uncompleted jobs.

ESSENTIALS OF A GOOD INCENTIVE PLAN

It is considered that the requirements of a good incentive wage plan are—

1. There must be a guaranteed minimum wage.
2. The plan must be just to employer and employee.
3. It must have the support of the management and the employees.
4. All standards should be based on time study.
5. Standards must be guaranteed against change unless methods alter.
6. The plan must be reasonably simple so that the employee can figure his earnings.
7. There must be a proper incentive; if the standard is high the reward must be generous.
8. There should be no restriction on the amount of earnings.
9. The plan must assist supervision and, if possible, aid team work.
10. The plan must not make costing difficult.

Each firm must choose the plan best meeting its own work and circumstances. There is no best made-to-order plan, and it is a good point to preserve flexibility in the system adopted. In any case, great care is required in the introduction of an incentive plan. The normal British operative resents what is new, scenting speeding up and driving in these matters, and it is necessary for the management to win the confidence of the workers, explaining what it is doing and the reason for and purpose of doing it.

A vexed point arises in how to deal with spoiled work. Various alternatives have been suggested: (1) make the workman do it over again in his own time, (2) put the workman on a time rate for the period covering the spoiled work, or (3) give no credit for spoiled work, but if it is not due to

the operator's fault, make a special allowance, such allowance having to be applied for first to the rate clerk or, if disputed, to the works manager.

INCENTIVES ON OTHER FACTORS THAN QUANTITY

Besides greater output, greater accuracy and higher quality should be encouraged. It is sometimes possible to pay a bonus on quality, for example, a graded bonus decreasing with increase in the number of rejects and ceasing altogether above a certain percentage. Waste may be discouraged by paying a bonus on savings in material, i.e. the bonus is inverse to the waste. Bonuses may also be paid on safety records, length of service, regular attendance, reduction of indirect labour or in maintenance costs.

PROFIT-SHARING METHODS

Profit sharing is a method of evoking the collaboration of labour with ownership by giving the workers a pecuniary interest in the making of profits. It is based on the idea that optimum output is only forthcoming when the worker can identify the success of the firm with his own personal profit. Profit sharing antedates time and motion study and incentive wage payments, one of the earliest profit-sharing schemes being that of the Maison Leclaire, started in 1840. On the whole, profit sharing has had a chequered, sorry history, a large proportion of schemes having been abandoned. The average life of schemes in this country has been 14 to 15 years and the average bonus 5 to 6 per cent addition to wages. From the workman's point of view it is claimed that the return is too small, too far off and too uncertain to be a fitting incentive to greater productivity, and such schemes may be directed against his trade-union loyalty and side-track his main interests.

Whilst it is highly desirable to interest all parties in the successful running of a works, it may be asked what role does the efficiency of labour play in the making of profits?

Profits are dependent on so many factors, for example the state of trade, the suitability of the plant, the manufacturing policy, wise buying, effective selling, efficiency of organization, and so on. It seems, therefore, more optimistic than practical to assume that efficient effort on the part of the workers may counteract any or all of the above factors which may be inefficient or wrong. Moreover, the incentive of profit sharing is generally absent just when it is most required, viz. when earnings and employment are low.

As it is not suggested that the workmen should share in a loss on the past year's working, the logic of the reverse is not apparent.

One might go further and ask what are profits, and are they ever known, or is it desirable that they should be known outside the highest officials of a firm, in view of the agreed necessity of reserves to ensure the stability of a modern undertaking?

Most profit-sharing schemes constitute a form of employer's benevolence, the rates and conditions of receipt (usually depending on length of employment) being fixed by the firm. So long as the true nature of profit sharing is recognized, it will be all to the good as an extra inducement to increased industrial efficiency and improved industrial relations. Moreover, there may be engendered a corporate spirit among the workers which will frown on waste of time and material in so far as this is conceived to lessen the chances of a bonus. Profit sharing is not, however, a form of payment by results, as a profit is not necessarily ensured by a high rate of production. It is in no way a substitute for the incentive systems outlined above in which there is a clear-cut and definite issue, viz. an extra wage payment for increased application to the factors within the workman's control.

CO-PARTNERSHIP

Profit-sharing may assume various forms and, whilst cash payments predominate, the bonus may be paid in

shares allocated to the workers from a block reserved for this purpose. It is, however, difficult to dissociate this from co-partnership. The latter implies that the employees become shareholders in the business, and it is assumed that their feeling of responsibility in this capacity will cause them to have the interests and welfare of the firm at heart and facilitate co-operation, thus diminishing or avoiding trade disputes.

There are several types of co-partnership schemes. Some are wholly benevolent, others are directed to making it as easy and convenient as possible for the employee to become a shareholder. In any case, labour is not as a rule in a position to purchase shares outright, and co-partnership is usually anteceded by the reservation of a fund to purchase the block of shares which the employees will eventually possess. Under the benevolent type the shares may be allocated to workers as their length of service increases, but they may hold no voting powers and must be sold back to the firm when the employees leave. In fact, restrictive conditions are nearly always imposed, even if the employee is merely assisted to buy the shares in instalments. Sometimes co-partnership committees are formed to advise the management on relevant matters and a representative of the employee co-partners may even sit on the board of the company, but control always remains with the employers.

It is generally agreed that contributory schemes are preferable and that trade unions should still be recognized and collective bargaining retained, though it is to be anticipated that a better spirit will be found in wage-bargaining operations. It is reported that about 50 per cent of co-partnership schemes have failed to continue. They are usually dropped in bad times. It has been pointed out that the employee-shareholder carries a double risk, viz. that of losing his capital and his job. Co-partnership schemes are most suitable for public-utility companies, but in ordinary industrial concerns the subject is bristling with

difficulties. Most people are agreed, however, that everything should be done to encourage and facilitate investment by workers in industry. The need of employees for security has been recognized in some cases by the company limiting their holding to special bonds which are not only secure but easily redeemable. It has also been suggested that the workers as a body should form themselves into an investment society registered under the Provident Societies Act.

The workers' representatives should be helped to acquire knowledge of the working of the industry and their own firm in particular. It will assist towards confidence and co-operation. Co-partnership schemes are, however, no substitute for an enlightened wage policy.

NON-FINANCIAL INCENTIVES

In addition to the hope of higher earnings from greater output, there are a number of inducements to further effort by employees, such as competition, fear of dismissal, and probability of continuous employment. There is also the mass incentive of activity and drive. Good management is in itself an incentive. Confidence in the management and belief in its sincerity and goodwill will stimulate output. Interest and pride in the work and knowledge of how the individual's work fits into the general scheme have a beneficial effect on output. The incentive of appreciation may be employed to stimulate loyalty and interest in the firm. Other incentives include encouragement of suggestions, good physical conditions and the reputation of a safe shop. Efficiency is encouraged by promotion possibilities. Promotion policies should be carefully reviewed, explained and charted. The adaptability of a live organization attracts a good type of worker. A good costing system is an incentive in itself. When workers know that costs are being carefully analysed and scrutinized they are impelled to maintain their efficiency. The efficiency value of good personnel officers has already been discussed.

Managerial incentives include adding to responsibility

and sense of authority, increased freedom of action and opportunity to build up an organization and performance against budgeted standards.

SHOULD FOREMEN BE PAID A BONUS?

There are a number of ways of paying a bonus to foremen, of which two will be mentioned: a bonus on the workmen's bonus, and composite bonuses related to various constituents of the foreman's responsibility, e.g. percentage of rejected work and average productive efficiency of the group, the number of standard hours' work accomplished, the time lost in delays, unit labour cost, percentage of scrap, reduced shop overheads, and so on. It will be seen that the establishment of these composite bonuses depends on the predetermination of good average shop practice in regard to the various factors.

There is a good deal to say for and against this proposal, but the author has been rather surprised to find that several discussion groups of foremen and supervisors have passed a majority vote against it. There seems, however, to be an extension of the principle of making incentive payments to foremen and, in fact, to every grade of executive.

TIME-KEEPING AND WAGE PAYMENT

Accurate time-keeping is the basis of wage analysis and ascertainment of labour cost. The work of the time office facilitates the correct calculation of wages by accounting fully for each workman's time, which ensures that productive labour is kept as fully employed as possible.

The method of recording time requires careful attention as it is essential to know not only the period that a man is on the premises but the time actually spent at work and on what jobs.

The traditional method of time-keeping comprised recording the former point only, for example, by a watchman at the gate who knew the men or had some

simple tally system in use. It is, of course, still necessary to record the total hours of attendance, and in some cases a double check tally system is used, viz. a main tally board at the gate and departmental tally boards under the supervision of the foremen. The time-keeper is able to keep a simple record (manual time-sheet) of absentees and late-comers, together with overtime hours worked. From the

Name				
No 26	Week Ending		Ord	Overtime
	1	2		
	7.55 SA 12.00 SA	7.55 M 12.10 3 1.30 3 5.30 3	4.05	
	7.55 Tu 12.30 Tu 1.30 5.30		5.35	

Wage Analysis				
Works Order No	Ord. Time	Over- time	Amount £ s d	Bonus £ s d

Total Hrs			Amt
Ord Time	Hrs. Mins	Rate	
Ord Time	47	= 2/-	4 1/6 -
Overtime			
Bonus			
Gross Wages			
Deduction	11 5" 14" 5 1/2 3 d		1 -
			4 12 -

FIG. 9. TIME CARD

point of view of on-and-off times, such a system may be as good as a mechanical recording system, but the latter gives more information. In any case, the time-keeper will allocate employees' numbers and instruct, if necessary, in the use of the recording system.

A good deal of clerical labour in issuing short-time or overtime slips and in making up time sheets is eliminated by the use of clock recording systems. The total hours per week are ascertained from the time card on which wages particulars are subsequently filled out as shown in Fig. 9.

The location of time-recording clocks requires consideration, especially in large works. Where distances are great, it may be preferable to have one at the entrance to each department rather than produce congestion at the main gate.

Routine at the clocks is too well known to need description. Both dial time recorders and card recorders are in use, but the latter are preferable. The responsibility for time keeping—lateness, absenteeism, overtime working, etc.—vests in the works manager, though he may delegate it, and the employment officer may occupy himself with this work. A chart of lost time and the cost of lost time should be kept.

JOB-TIMING

Where the operative is not engaged on work of a continuous nature, lost time may easily arise and job-cards should be used, which are time-stamped by a clock recorder in the shops. The job-time total must be "agreed" with the worker's in-and-out times, any disagreement representing idle time from machine breakdown or other cause.

Manual time sheets are still used with columns for Order No. and Beginning and Finishing Times, which the employees fill in and the foreman countersigns, the columns for total hours and money values being filled out in the time office. Automatic time records are, however, always preferable, though special cases may arise, e.g. in the case of gangs or of service work. Care should be taken to see that there is only one card per man per job and that the job clerk has the next job in order with the card ready.

PAY-ROLL COMPILATION

Efficiency in the preparation of pay rolls depends on the soundness of the time bookings. Simplicity is the desideratum of any system.

In time books the daily entries are totalled for the preparation of wages sheets. Suggested headings for the latter are: Clock, No., Name, Rate, Hours, Wages, Overtime, Bonus, Total Wages Deductions, Net Wages. Copies will be sent to the cashier and the cost office.

As much use as possible should be made of labour-saving machinery, but for comparatively straightforward wage

extensions a ready reckoner is usually regarded as superior to the calculating machine.

There are many pay-roll machines in use, for details of which specialist books should be consulted as well as for particulars of pay-roll compilations, by means of the Burroughs machine or the Hollerith or Power-Samas equipment. A Burroughs machine will give the pay roll, a record of earnings, a pay envelope and a receipt in one operation. In punched-card systems not only are the clock cards used as original documents but as permanent records of "punched" information. In addition to preparation of a summary, any desired analysis of the information may be made by simply running the cards through the tabulating or sorting machines. These machine methods are also useful for the preparation of statistics and records, such as National Health and Unemployment Insurance data, income-tax returns, trade association returns, and so on. Another advantage lies in the fact that as output, direct and indirect wages, etc., can be quickly ascertained many "management ratios" are readily available for the use of the works manager, employment officer or other officials.

PAYMENT OF WAGES

From the firm's point of view the payment of wages is an unproductive expense and must be reduced to a minimum cost. Many firms find automatic cashiers of much utility in making up wages, and other time-saving devices are available for folding notes and sealing envelopes, the sealed-envelope method of paying wages being the one most used. Time economy in the stamping of insurance cards results from the use of a mechanical affixer.

IMPORTANCE OF INTERNAL CHECKS

In all pay-roll systems checks are necessary to prevent or to locate possibilities of fraud and error. These checks may not mean duplication of effort, but a good safeguard against collusion is the subdivision of duties so that the

results of the work of one man or a department will prove a check on another. Check control is necessary in the following: time booking, extension of time wages, calculation of piece-work amounts, posting piece-work amounts to the pay roll, totalling of gross wages, cash analysis and make-up and actual wage payment.

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CHAPTER III

DESIGN ADMINISTRATION AND QUALITY CONTROL

DESIGN ADMINISTRATION

DESIGNING and drafting is one of the major responsibilities of management, the design office being an important intermediary between it and the works. The quality of a product depends on the efficiency of its design, the quality of the materials used and the quality and accuracy of the workmanship involved in its manufacture. It will be seen, therefore, that the first consideration is to get the product right on the drawing board, and it may be mentioned that the key-note is simplicity consistent with efficient service. The second point involves the establishment of standards, and the third demands the spending of time, thought and money on inspection.

QUALITIES OF A DESIGNER

If the design of a product is not right, the work of the other departments is wasted or inefficient. Moreover, in the highly competitive markets of to-day the designer must be much more than a skilled draughtsman. He must have a flair for commercial success, imagination, vision and inventiveness, but at the same time a sense of design from the manufacturing point of view. This combination of the appreciation of manufacturing and commercial value is rare, but necessary to enable the designer to keep the balance between the works manager and the purchaser. on the one hand who are concerned with minimizing costs and the sales manager on the other, who is always pressing for better quality, finish and efficiency.

The designer must always bear in mind the effect of design on costs and have a sufficient knowledge of the work of the shops to choose a design involving the most

economical manufacturing procedure. However carefully designed a machine may be and however fully it meets mechanical requirements, it may be commercially worthless if in fact it cannot be sold at a profit. On the other hand, a machine need not be scientifically perfect if it will fulfill the purpose for which it is designed. This need not mean, however, that the machine will be so shoddy that the cost of maintenance and after-service will be exorbitant.

The designer must have a knowledge of materials which will permit him to select those most readily and economically worked. He must be conversant with the machines available and their capabilities so as to adapt designs to ready and cheap performance, and so that the operations may be carried out on those having the lowest machine-rate to carry in overheads. He must use standardized components wherever possible as this affects the runs of work and reduces assembly costs. He must not only be able to design jigs and fixtures, but understand the economics of their employment.

It is evident that the key-note of the designer's job is co-operation, not only with the shops but also with the remainder of the organization.

The departments responsible for the production of the drawing-office designs must be specially considered. Designs must be submitted to those who have to reproduce them with a view to utilizing their knowledge of cheap and rapid processes, preventing the use of costly tooling operations, avoiding the cost of special machines, and so on.

If the progress department finds that delays arise on the schedule for certain parts, the designer must first see if modifications cannot be made for more rapid manufacture before extra plant is considered. Although he specifies the materials, the designer must co-operate with the purchasing department for lowest all-round cost.

With the Estimating Department the designer will co-operate on new projects, also with consulting specialists, if such are employed.

Some engineering firms have resident engineers on a project, and these will, of course, gain experience of inestimable value to the designer. Similarly, the designer's attitude to users of his firm's products must be one of co-operation.

Being correct to start with is so important that no opportunity for consultation before finality is reached should be lost with a view to lowest overall costs consistent with satisfactory service.

The reports of the inspection department should be studied to see if the rejections or the reasons for rectification are associated with any fundamental weakness in design.

FACTORS INFLUENCING DESIGN

Besides taking into account the mechanical problems involved in economical manufacturing methods, the designer will be concerned with the safety of the operator of the product and its ease of handling in the plant and on shipment. There are also many other points to which his attention should be directed from the sales point of view, such as the influence of pleasing lines and finish, floor space occupied, accessibility, flexibility and easiness of control, "fool-proofness" and low upkeep and service costs.

In the past there has been a general tendency in British engineering designs towards unnecessary weight and rigidity, whereas lightness and ease of handling might have been attained by simplification without sacrifice of safety.

DESIGN DEPARTMENT ORGANIZATION

The evolution of design involves two lines of work—

1. Calculations and consideration of performance, the preparation of functional drawings and design on scientific lines.
2. Design from considerations of production and use and the preparation of working drawings.

The drawing office is usually sectionalized into design divisions as follows—

(a) Analytical Section in which mathematical, mechanical and electrical calculations are made. It will co-operate with the Research and Development Department and make and receive suggestions as to lines of enquiry.

(b) Standards and Specification Section. Information will be prepared in tabular form for the use of draughtsmen and the shops. Specifications and assembly lists are issued to facilitate production in accordance with requirements.

(c) Drafting Section. The time of preparing drawings and drawing costs will receive the attention of the chief designer.

(d) Checking Section. Care should be taken to check dimensions in relation to the sequence of operations. Alterations are a prolific source of mistakes. Recalling and cancellation will receive special attention.

(e) Blueprint and Record Section for filing and storing.

STANDARDIZATION OF DESIGN

Lack of use of standard parts and of interchangeability of components has in the past been an irritating and wasteful fault of designers. The designer must guard against the use of needless patterns and different sizes of screws and bolts, and must employ, wherever practicable, similar parts in different types of machines so as to permit manufacture in economical quantities. He must use standard materials if possible, employ standard limits on working drawings and avoid needlessly fine tolerances. Examples of standard units which may be used are governors in steam engines, differentials in cars, ignition units and starters. The designer must have a thorough knowledge of the advantages of standardization in relation to its economy, for example, in jigs, fixtures and tackle.

CONTROL OF DESIGN

Working drawings are a record of the product as finally designed and made. Drawings should give every particular

and be subdivided into units, showing one component only. One machine must not be held up because the drawing is in use at another.

Classification and identification of drawings are important for ease of reference. They may be listed alphabetically or numerically or by a combination of these methods, and corresponding patterns, components, sub-assemblies, etc., should bear the same code number. If changes in design are made, all outstanding blue prints must be recalled and the code number altered. Consequential changes must be carefully studied, for example, the effect on tools, patterns and fixtures.

Reference may be made to the use of preliminary models in design, not only for visualizing the proportions, but for determining clearances and the relative motion of parts, and to test operating characteristics.

DESIGN AND MANUFACTURE

It is a truism that the draughtsman must see his design through production spectacles, but his knowledge of processing may not be called into play until an experimental or research design has been made and tested for mechanical efficiency. This stage in the development of a new product may require months of intensive work. When the new product has been proved satisfactory from a technical point of view, the design will have to be gone over again, component by component, from the production point of view. A slight change in design may make it possible to use parts interchangeable with other jobs. Tools, gauges and jigs will have to be designed with an eye on ultimate costs and not first costs. Data for purchasing, manufacturing operations and quality standards will have to be provided. Materials will have to be selected with a view to a steady flow of work; designs for foundry work will not have to be of impossible thinness or of a type which cannot be drawn from the mould; drawings will have to show all the requisite information clearly so as to avoid

delays in the shops; specifications will have to be precise; and all drawings and specifications will have to be issued in advance of the scheduled start of manufacture.

Examples of the practical workshop knowledge required by the draughtsman include allowances for shrinkage as in dies for forming hot metal, in bending sheet metal, and in grinding or finish machining work, the avoidance of unnecessarily intricate moulding or machining operations.

EFFECT OF DESIGN ON COSTS

A cost-reduction sense is essential in the drawing office, and a steady team effort should be exerted towards lowered costs of production. An important factor is simplification; from many points of view the simplest is the best. The draughtsmen must keep abreast of changes in manufacturing methods so as to substitute cheaper for more expensive operations. Improvements in materials must also be carefully followed.

Savings arise from very simple changes such as the way in which sheets are cut or laminae stamped from strip. The welding of pipes together to form a line is cheaper than using flanges, or when flanges are essential it may be cheaper to weld on the plate type instead of screwing them on.

In practice it is more generally a question of redesign to reduce costs than starting with low cost designs. Simple examples include the simplification of radio transformer bodies so that bent aluminium strips could be used instead of castings, and the redesign of a spade handle so that the operations were reduced from seventeen to nine and the total cost per handle reduced 80 per cent.

The effect of design in connection with machining costs may be illustrated as follows—

In the first design of a bearing support, it had to be chucked for turning, and then re-chucked for boring, with, a final difficult grinding operation.

A second design was got out in which the whole of the machining was done in one setting, but the grinding operation was still difficult.

A third simplified design was then made by which the whole machining was still done with a single chuck, but all the operations were easy and accessible and the cost was considerably cheaper.

A change in design of a machine base was made which permitted it to be built up of angles and bars instead of castings being used. The welded machine base proved 37 per cent cheaper to make.

The design of a portable electric drill was altered to permit the use of pressed-steel casings and other parts instead of aluminium cases. The parts were punched and formed in presses and spot-welded in jigs to ensure interchangeability. In quantity production, the cost was reduced by at least a third and the weight also proved less.

By altering the design of a small casting to make it a pressure casting, instead of a moulded job, the cost of the die was saved on the first 200 off.

Other examples of changes in design to permit more economic methods may be cited in making wheel hubs of pressed steel, differential gears by upsetting one end of an axle bar, ball-bearing rings by upsetting them from plain bars, and so on.

Reference should be made to the limit of the rate at which it is economically permissible to incorporate changes in design of manufactured products. In a firm making special sizes as well as standard products it is advisable to try out a change in design on those sizes of which only a few are made. A change in a standard line made in large quantities may prove an elaborate undertaking, involving perhaps jigs, fixtures, special machines and processes. The disclosure of an unsuspected weakness after mass production has commenced would prove a serious matter. An example may be quoted in the case of transformers.

*
STANDARDIZATION

Standardization dates back to the beginning of history, speech, writing, measurements, time and weight being the basis upon which civilization developed. Fundamental standards are appropriate for the Government to establish. Industrial standardization, with which we are concerned, is of much more recent origin and based on mutual consent and co-operation of all interested parties. It signifies the simplification and unification of the requirements of industry by the collaboration of the producer, the merchant and the user. This bringing together of manufacturer, distributor and consumer to modify their requirements by agreement focuses the best thought and practice, and the co-operation and unity of action engender constructive forces which tend to eliminate waste and yield fruitful economies.

Industrial standardization is a natural step in the scientific development of engineering and is merely carrying specialization to its logical conclusion. The wastefulness of a great number of individual specifications and a wide diversity of patterns and sizes is readily appreciated. Moreover, everyone is aware of the great difference in price between standardized and non-standardized articles such as boots, clothes and motor-cars, tin boxes, etc.

Standardization is the basis of interchangeable manufacture and of mass production and probably the greatest economic factor in the growth of the engineering industry during the present century.

Standardization has a greater scope in parts and components than in finished products, and it is more difficult to introduce into old-established than new industries owing to the large invested capital that might have to be scrapped or the heavy investment required to carry out a thorough-going scheme.

Moreover, owing to the principle of voluntary standardization, unwise standards cannot be forced upon an unwilling industry or public. There is no danger of standardizing

anything simply for the sake of standardization. Once industrial standards are established they do not preclude improvement, advancement or innovation and the introduction of new processes. Frequent and careful reviewing of industrial practice readily permits such changes as may be desirable. The preparation of a standard specification necessarily involves the pooling of a large amount of technical knowledge and experience not otherwise obtainable, and, in addition to the confidence thus generated, the same knowledge and experience are best qualified to indicate when a standard is obsolete or obsolescent.

SIMPLIFICATION

Simplification means the elimination of unnecessary varieties of a product, in the sense that they cannot be justified on economic grounds. A single item or part is used for as many purposes or classes of product as possible. The number of patterns, sizes and styles is reduced to a minimum. The continuous production of a few types saves the starting and stopping of expensive machinery, and the waste of time in set-ups and changes of materials. In addition to longer manufacturing runs and higher production rates, simplification results in less capital being tied up in stocks and less storage space; in fact, it introduces many sources of economy. Simplification received a considerable stimulus during the War, and the work of the British Standards Institution in this direction is well-known, so that only a few examples need be given, viz. steel sections, tramway and colliery rails, haulage ropes, electric cables, telegraph poles, studs, bolts and nuts, washers, etc.

The motor and cycle industries provide an excellent illustration of how simplification of types and standardization of components have increased efficiency at greatly reduced prices.

Simplification also modifies the sales technique, i.e. sales have to be achieved on quality (relative to price), not on novelty.

AIMS AND OBJECTS OF STANDARDIZATION

The objects of industrial standardization involve the determination of suitable dimensions, qualities, types and performance and the establishment of performance tests. These increase production and facilitate maintenance, and result in reduction in unit costs. Interchangeability is advanced and efficiency and safety in use are increased. In manufacturing, standardization aims at savings in production time from continuity and system, and the economy that arises from large-scale production.

In the past, trade has been handicapped by lack of precise knowledge of technical requirements or performance, insufficient stocks and poor methods of distribution. Standardization aims to simplify buying and selling, provide adequate stocks or prompt delivery, and facilitate and cheapen distribution.

FIELD OF STANDARDIZATION

Industrial standardization covers a very wide field, including—

1. Nomenclature or the setting up of standards for definitions, terms, symbols and abbreviations. It is considered that this classification of terminology is the correct way to start any systematic standardization.

2. Dimensions. The fixing of tolerances and allowances is the basis of assembly and interchangeability. The inconvenience and waste of multiplicity of dimensions and lack of standards of form and size are well illustrated by screw threads before Whitworth's work. The standardization of such items as wire and sheet gauges, sections, threads and connections has obviously been invaluable. The dimensional specifications of the B.S.I. are related to the various industries.

3. Quality of materials. This is of interest to all industries. In some cases the composition as well as the properties of materials is specified. The specifications

indicate the permissible minima. These standards assist production in many ways, facilitating buying and inspection and a uniform flow of work during processing. Although standards multiply as new materials come into industrial use, there is not only a desire but a trend to a minimum number of standards. This section includes standards of sampling, analysis and testing.

4. Tools and equipment. This, of course, is based on No. 3. F. W. Taylor took thirty years to standardize simple lathe tools, partly because there was no standard tool steel to start with. Standardization is, of course, extended to drills, reamers, milling cutters and taps and dies, grinding wheels, belting, and so on. Built up logically and enlarged step by step, the system is extended to complete engines, motors, and other equipment, e.g. specifications for triple expansion marine engines, boilers, oil engines, cranes.

5. Processes. If tools and equipment are standardized, there is a possibility of standardizing methods or the most efficient way of doing a job in the light of present knowledge. In addition to the scope in mechanical processes, standards have been drawn up, for example, on the determination of the fusing temperature of coal ash, baking varnish, drawing office practice, street lighting, etc.

6. Performance or rating of machines to show, for example, whether a so-called 100 h.p. electric motor will do what is claimed for it. Standards have been drawn up of the performance of generators, motors, converters, transformers, engines, etc.

7. Safety, e.g. the factors of safety in design, construction and installation in a crane. Considerable work has been carried out by the Standards Committees, in some cases at the request of the Home Office, and with the active support of industry.

ADVANTAGES OF STANDARDIZATION

Standardization permits the manufacture of a more regular, reliable and, in some cases, improved product at a

lower cost. It expands demand and broadens markets. By permitting the accumulation of stocks during slack periods, it exerts a stabilizing influence on production and employment or minimizes the ill-effects of seasonal demands by levelling up the labour load. It reduces manufacturing costs in many ways. Less machinery is required for a given output, time is saved in set-ups and re-assembly, the turnover is increased and overhead costs reduced. It simplifies clerical and costing systems, supervision and inspection and the instruction of employees. It renders available large supplies of materials and labour in an emergency.

The expense of carrying stocks, of maintenance and of repairs is reduced. There is less idle capital in fewer patterns and sizes. The development of more efficient machinery and new methods is facilitated and greater interchangeability of parts is encouraged. Complicated operations are minimized, and there is reduction in the cost of preparation of drawings, specifications, and tenders. Delivery is, of course, expedited.

Standardization suppresses confusion merely for sales effect ; the work of the salesmen is facilitated and selling costs are reduced. Fewer mistakes are made in ordering, the supplier really knowing what the intending purchaser requires. There are fewer misunderstandings in trade, as the purchasers know what they are getting.

DISADVANTAGES OF STANDARDIZATION

Standardization to some people suggests a dead low level of uniformity and monotony, the retarding of invention and design, the elimination of individuality and the cessation of progress. Stagnation of design and crystallization of practice may make changes difficult to achieve. It is suggested that the growth in repetition work involved degrades the workers into mere machine workers and accelerates the disappearance of the craftsman. Moreover, as our standards may not appeal to the foreigner, standardization

militates against meeting the requirements of export markets. In so far as these suggestions contain latent possibilities, it is essential to guard against standardization stultifying progress and hampering trade. There is no virtue in the mere desire to be different, but there is as yet little danger of standardization being carried to extremes.

STANDARDIZING ORGANIZATIONS—BRITISH

In 1901, on the initiative of Sir John Wolfe Barry, an Engineering Standards Committee was formed by representatives of the Institution of Mechanical Engineers, the Institution of Naval Architects, the Institution of Electrical Engineers and the Iron and Steel Institute. This Committee appointed sectional committees which called in representatives of the Admiralty, the Board of Trade, the Classification Societies, manufacturers and independent experts, and approached the work in an orderly manner. It was found that there were about 300 different sections rolled in British steel works and the work of simplification started. Standard test pieces, methods of testing and standard tests were decided upon, the first list being published in 1903. By 1905 there were thirteen sectional committees and 250 persons on sub-committees.

In 1918 the Engineering Standards Committee was incorporated as the British Engineering Standards Association. In 1929 a Royal Charter was obtained, and the main Committee became the Council. A demand for an extension of scope led to a supplementary Charter in 1931, and the British Standards Institution was formed with a General Council and Divisional Councils for engineering, building and chemical industries and provision for a Textile Council. The work of the four main divisions is subdivided into industry committees, which supervise about 600 specialized technical working committees. About 3500 engineers and business men form the representatives on the technical working committees.

The engineering industry committees cover aircraft, chemical engineering, colliery requisites, electrical, gas, illumination, iron and steel, mechanical, non-ferrous metallurgy, petroleum and public works with about 175 technical committees and many more sub-committees.

The preparation of a British Standard specification is only undertaken if, in fulfilment of a generally recognized want, producers and users are prepared to co-operate and the necessary funds are forthcoming. Standardization must be arrived at by general consent and periodical review and revision must be undertaken. Any individual or group of individuals has a right of appeal to the Divisional Council and then to the General Council if there are any objections to provisions in a specification.

The work of drafting the specifications is in the hands of the technical working committees. The widest possible scope is given for comment and criticism. Catalogues are available covering about 600 specifications. The economic value of the work is widely recognized, and millions of copies of current specifications are in circulation.

The Handbook of Information issued twice a year gives a list of B.S.I. specifications and particulars of new specifications in preparation. The annual report gives particulars of the Institution's work during the preceding year.

The whole of the technical assistance and funds of the Institution is obtained by voluntary contributions from the supporting organizations and the sale of its publications with the addition of grants from the Government, the Crown Colonies and India.

DOMINION STANDARDIZATION

National standardizing bodies in close liaison with the B.S.I. exist in all British Dominions, but not in India, Australia alone having about 500 technical drafting committees. There is an interchange of final draft specifications for examination and comment.

The Imperial Conferences in London in 1926 and 1930

drew attention to the necessity for the co-ordination of specifications within the Empire, and the Ottawa Conference in 1932 gave a further stimulus to imperial standardization with a view to the encouragement and increase of trade.

INTERNATIONAL STANDARDIZATION

Differences in language, units of measurements, and in trade practices are barriers in international trade. A number of specifications have been translated into French, Italian, Portuguese and Spanish, and the Institution keeps in touch with the requirements of foreign markets to assist British export trade. Probably only nomenclature can yet be profitably discussed from the point of view of international standardization, but the Institution keeps in direct touch with the work of the International Federation of National Standardizing Associations. The Electrical Industry Committee is also the British National Committee of the International Electrotechnical Commission.

STANDARDIZING ORGANIZATIONS—FOREIGN

American legal standards are under the charge of the National Bureau of Standards formed in 1901. The American Standards Association is the national voluntary organization comprising some 600 member-bodies. It works in close co-operation with industrial organizations such as the American Society of Testing Materials, the Society of Automotive Engineers and the American Institute of Electrical Engineers. At the present time there are nearly 900 standards in use and about 450 tentative standards.

German standard specifications are under the supervision of the Deutscher Normenausschuss in co-operation with government departments and trade associations. All approved standards bear the symbol D.I.N. More than 4500 standards have been completed and over 250 tentative standards published. They are published in the form of convenient handbooks for the use of industry.

In Russia standardization has an important place in the plan for national economy under the control of the All-Union Scientific Research Institute of Metrology and Standardization, the present methods involving co-operation between industry and consumers. The number of approved standards approaches 5000. Complete plants are being designed on standard lines to meet the demands of various industries.

BRITISH ENGINEERING STANDARDS AND FOREIGN MARKETS

- Comment is sometimes made on the wider margins of strength and higher factors of safety in British engineering products than in many of foreign origin, entailing higher costs of production and distribution. It is estimated that two-thirds of our total output of machinery are absorbed by the home market, the remainder being equally divided between the Empire and foreign markets. British goods are seldom, if ever, excluded from a market because of inferior quality. They are superior, but dearer. They may be a more profitable long-run investment, but the foreigner usually does not believe it. Lighter machines and structures are designed and made abroad and function satisfactorily; in fact, a great part of the world's work to-day is being done by, from our point of view, inferior machinery. The question arises whether in view of the admittedly high level of our material standards, our factors of safety and weights are not unnecessarily high and ought to be reviewed with the object of a more efficient utilization of the strength of our structural materials. On the other hand, it is sometimes contended that British traditional structural rigidity is necessary to obtain even the initial requisite accuracy of performance, as in machine tools. Nevertheless, a good deal of informed opinion favours the view that progress in metallurgy, the development and refinement of methods of production and construction, gauging and testing, and particularly improvements in the science of design should

permit the achievement of economy by lighter structures without sacrifice of product quality or safety of the operator or user. Alternatively, if machines constructed to a less rigorous standard of performance are good enough for all practical purposes, especially in view of the enhanced liability to obsolescence, this must be faced up to, at least in relation to our export trade.

EXTENSION OF STANDARDIZATION

We are mainly concerned here with engineering standardization by national bodies, but it must be remembered that the principles of standardization may be extended within a firm beyond the regions covered by national specifications. Scientific management is based on classification and standardization, not only of materials, machines and products, but also in operations and procedure. Operation standardization depends on the determination of the most efficient movements and processes, followed by time studies with a view to introducing standard procedures, performances and wage rates. Without standard performances compilation of production control boards or charts would be impracticable.

The advantages of standardization apply to other business functions than production, and its effect is to be noted in safety provisions and in office procedure, e.g. in records, accounts, forms, etc.

QUALITY CONTROL

ECONOMICS OF QUALITY OF WORK

Apart from financial reasons, all customers or consumers always want quality, which, read in a wide sense, means excellence of an article for the purpose in view. Standards and specifications in themselves tend towards a more satisfactory and consistent quality, but, in spite of this, departure from the desired quality may arise from accidental manufacturing errors or the human factor, e.g.

inexperienced or careless workers. Competitive buying tends to reduce prices and therefore quality, and, however complete a specification may be, the need of inspection will still remain. High quality invariably gives better service and longer life, but low initial cost is a strong attraction. It is always possible, however, to make an article worse and therefore cheaper than somebody else, and those to whom a reasonably high standard of quality and reliability is essential realize that this cannot be ensured without adequate inspection and test.

• ECONOMICS OF ACCURACY

Commercially, there is no such thing as exactly to size. In this sense it is impossible to reproduce a dimension with absolute accuracy. Precision is measured by the amount of variation between alleged duplicate parts. It is necessary to fix the permissible variation for different types of work. Tolerance is the difference in dimensions prescribed in order to allow for unavoidable imperfections in workmanship. Obviously, the absolute limits are the maximum and minimum sizes of each part between which it will function properly. In settling working limits, the work must be planned from the economic point of view or in other words they must be established with reference to the expense of manufacture. From the commercial point of view, the limits must be fixed as wide apart as possible consistent with the production of an article which will fill the requirements.

Taking as an example the question of fits, of which there are four usual classes, force, driving, push and running, standard allowances are prescribed for different qualities of work (Newall Standard or B.S. running fits). In fixing allowances, due regard must be given not only to practical considerations (e.g. working conditions, temperature, and lubricating conditions), but also to the cost of production so as not to prescribe unnecessarily accurate work for the purpose in view.

ECONOMICS OF GAUGING OR CHECKING WORK

In workshop practice gauges are used to ensure that any given dimension is within the tolerance laid down for the class of work to be produced. Their use depends on the amount of production, but obviously spoiled parts must be eliminated as quickly as possible, and in modern commercial work efficient means of gauging are imperative. There are many kinds of gauges in use, e.g.—

1. For absolute measurements—scales, verniers, micro-meters, comparators.

2. Single-purpose gauges—snap, ring, plug, concentricity, ring thread and plug thread gauges, templates, hole location gauges.

3. Mechanical gauges—amplifying gauges, expanding plug gauges, uniformity of motion indicators, dial indicators for contours or profiles.

4. Optical gauges—magnifying, projecting.

A thorough-going system of gauging is costly, but it is usually found that a liberal expenditure is cheapest in the long run. In interchangeable manufacture it is, of course, essential. Usually the simpler the gauge, the more efficient it is as well as the less costly, but steps should be taken to overcome the necessity of multiplicity of gauges. Two or more individual snap gauges may be replaced by a stepped gauge. Adjustable gauges overcome throw-outs due to wear. Wherever possible, gauges should be such that they will function without the work being removed from the machine.

The accuracy of the gauges is important. It may depend on the manufacturing tolerances or may have to be dead to size. Suppose, for example, it is necessary to have identical gauges in different shops. The limits of inspection gauges will be within the limits of working gauges. It may or may not be necessary to have master gauges. Primary standards (gauge blocks) are expensive and it may be sufficient to send secondary standards for periodic check.

ECONOMICS OF INSPECTION OR CONTROL OF QUALITY

The object of inspection is the attainment and maintenance of standards and specifications. Not only does a firm's reputation accompany its products, but defects and failures are costly. Defects may arise from unsatisfactory design, inferior materials, improper mechanical or other treatment, or careless assembly. The role of inspection in an economic production scheme may be likened to a multi-stage sieve or screen. On to the top screen the various raw materials pass, those up to standard passing through, the rejected oversize being the defective materials. The second screen is the part or component inspection, so that defective parts do not reach assembly. The third screen eliminates unsatisfactory assemblies, and the fourth or product inspection ensures that only units that are 100 per cent right reach the consumer. In other words, material inspection eliminates manufacturing troubles and avoids the expense of wasted materials and of time spent in machining and fabricating them; component inspection makes assembly easier and more efficient; product inspection ensures correct functioning and safeguards the firm's reputation.

MATERIALS INSPECTION

Materials pass through the inspection department on their way to the stores. One of the worst forms of waste is inefficient inspection at this stage owing to the losses which it may entail at subsequent stages of manufacture. As materials are now usually purchased to specifications, they must be examined in the light of these and certificates duly issued. The inspection depends on the work, the materials or the function the components made from them have to perform, and includes the following: measurement, chemical analysis, tests of mechanical, physical, electrical, and thermal properties, optical or X-ray examination,

endurance or life tests and trade tests. If the "raw" materials are finished parts, they must be correct in every detail and may have to be specially tested, e.g. undergo pressure tests and performance tests.

With the increase of automatic and semi-automatic machinery, the importance of efficient material inspection has increased, as with a high output volume serious losses may quickly arise. As the inspection department must provide the purchasing department with guidance in its commercial work, certificates of rejection must always state the reasons and acceptance certificates the test results. Mere "O.K." notes do not permit the most to be made of inspection reports.

INSPECTION DURING MANUFACTURE

Inspection during manufacture involves not only inspection of machining processes, but also equipment and tool inspection, inspection of assembly and erection, and final tests, which may include running performance, consumption and acceptance tests. Adequate inspection during production eliminates hand work and fitting during assembly.

In the manufacture of parts or components the question of floor versus centralized inspection arises, as to which permits the more rapid and efficient handling of the work in the shop. The question is important as the throughput of shops depends on adopting the right amount and type of inspection. It is impossible to draw any hard-and-fast rule, but centralized inspection sometimes leads to considerable waste of time. Faults and defects should be detected immediately they arise, but, in any case, there is a greater saving in detecting faults while the operation is in progress than after a given batch is finished. With the growth of repetition work the importance of early detection of errors has been increased, and it is now a general practice not only to inspect the first few pieces from a set-up, but to keep an eye more or less continuously on the work

coming through. With automatic machinery, as soon as an inspector notices irregularities a rectification order is put through.

We have referred above to the basic importance of precision in interchangeable manufacture. For interchangeability drawings must be dimensioned from working or register points as the tolerances are closely controlled. The smaller the tolerances the more frequent is the necessity for inspection.

ORGANIZATION AND STAFF

A feature of industrial development is the rising status of the inspection department. We have seen the multiplicity of duties to which inspection extends, e.g. control of standards of materials, during manufacture, assembly, testing, salvage, heat treatment, jigs, tools and fixtures. In a large works the post of chief inspector is obviously a responsible one, though, in fact, the inspector may have greater powers of discretion in a small works than a large one.

It is important that the department be independent, but it must be effectively co-ordinated with the rest of the works and the sales department so that the inspectors may know how their job relates to the other phases of the firm's activities. No one but the inspection department must have the authority to pass or reject materials or jobs. If the factory can overrule these decisions difficulties may develop later. Although in practice the inspectors may frequently be responsible to the works manager, it is easy to imagine that the latter, being anxious to keep up production at all costs, might tend to lower the standards, and the reliability and service of the product in the hands of customers might be prejudiced. The question of the responsibility of the chief inspector is a thorny one, but it is at least worthy of notice that in some firms the above difficulty is so far appreciated that he is responsible to the general manager or the progress manager or even the

secretary of the company. In any case, if the decision of the chief inspector is to be overruled it should only be after consultation between the managers concerned with the product.

The efficiency of the department depends on the employment of suitably qualified labour. An essential characteristic is reliability. The labour may vary from girls (e.g. for "go" or "not-go" gauging) to qualified engineers, according to the type of work. In engineering inspection, the inspection staff usually needs a special training and should be chosen from types having versatility, keenness, and quickness at work and a sense of anticipation. It should be capable of making concise and accurate reports which set forth the essential particulars at a glance, with adequate reasons for decisions.

COMMERCIAL BACKGROUND OF INSPECTION

The cost of inspection staff and equipment is an expense which is ultimately borne by the consumer. In spite of its importance, this overhead must be kept to the minimum consistent with maintaining the quality of the product.

Only such inspection and tests as are absolutely necessary to ensure efficiency and safety should be carried out and done in the most economical manner. In deciding whether an inspection operation is necessary, a point to bear in mind is whether its omission will make possible rejection at a later stage or prove a source of failure in service. The value of the test or inspection must be considered in relation to its effect on the price of the product. Economy in inspection may possibly be effected by considering whether 100% examination is necessary or can be replaced by percentage testing or periodic selection of samples.

The cost of inspection must be judged on its use to the higher control. The amount of inspection must be scientifically determined by what is best for the class and

amount of work in question. In other words, its cost must be reasonable in all the circumstances judged against the commercial background. Setting the right standard or degree of inspection, in fact, always involves a compromise between the opposed views of the sales department on the one hand and the production and progress departments on the other.

Inspectors should have a good knowledge of the use of what they are inspecting so as to take an economic view of the job with regards to its function. Inspection is something more than looking for defects and bad work; the inspector must be able to differentiate between accidental manufacturing errors and poor-quality work.

In all quantity-produced articles there will be minute deviations from the standards laid down which do not affect the ultimate performance. The inspectors must appreciate that the dangers of arbitrary or over-scrupulous inspection may be as great as those of inefficiency. It is, for example, uneconomical to insist on closer tolerances than are essential. Inspection should have an accelerating not a clogging effect on production; it is intended to be preventive rather than corrective. The waste and delay through retarded delivery caused by an over-constitientious inspection may rise to unbelievable heights. Inspecting does not mean mere arresting work which is wrong; it should involve saving, not rejecting, a job if any practical means is available for effecting a remedy. The inspector must have a thorough knowledge of rectification, re-treating, and repairs by welding, deposition, etc. He must co-operate fully with the salvage department with regard to spoiled work and maintain scrap at a minimum.

INSPECTION RECORDS

The utility of the inspection department depends a great deal on the records it provides. It should get together and tabulate the nature and percentage of defects so that the facts and statistics may be used by the management in

the interests and service of the firm. The proper handling of inspection results may provide many useful suggestions and improvements by locating production troubles, lack of balance, or actual wastage. Besides showing up bad or slow work, the department's conclusions, reasons and recommendations will enable remedies to be evolved, and may indicate that a revision of existing standards is necessary.

INSPECTION OTHER THAN IN MANUFACTURING

Inspection during production is not the only branch of general engineering inspection. In addition, we have inspection by the following—

1. Government departments and municipalities. Inspection, carried out by permanent staffs, is usually keen and may be severe. Over-rigid specifications sometimes result in high costs.

2. Insurance companies. Inspection is usually very efficient, the companies having done a great deal to increase reliability in all branches of engineering.

3. Consulting engineers and architects, more particularly concerned with buildings, bridgework, and other large engineering schemes.

4. Inspection specialists, usually employed when the amount of a firm's purchases does not warrant the employment of a permanent staff. The status of professional inspectors was raised by the formation in 1919 of the Institution of Engineering Inspection. Although these professional inspectors are employed by the purchaser, they must inspire confidence in the manufacturers and know the tricks of the trade.

The economic justification of organized engineering inspection from the point of view of the purchaser is that he secures the maximum efficiency in the expenditure of his capital. Apart from this, a single serious accident may outweigh many times the cost of inspection, e.g. in the failure of overspeed governors of steam or water turbines. Prices may be so cut under competition that materials

and workmanship suffer, and the greater the margin between the average and the accepted tender the greater is the need for inspection. Other features increasing this need are the remoteness of the destination of the plant from the place of manufacture, the increase in the indirect cost due to a breakdown, and the ratio of the cost of the specific piece of plant to the total capital expenditure. Engineering inspection to secure a plant adequate for its duties must be considered.

An economic problem arises in the case of a large concern which purchases plant and materials from all parts of the country, viz. whether to employ professional inspectors or its own staff, and whether the latter should be resident or travelling. If there is sufficient work the staff is justified and centralization also secures unity of attitude.

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CHAPTER IV

ECONOMICS OF PRODUCTION

(1) PRODUCTION PLANNING

PRODUCTION involves the organized utilization of natural resources, capital, and labour, and though the relative importance of production factors changes, the most valuable contribution to productive power comes from the mental and physical powers of the people. In modern times, owing to the rapidity with which scientific knowledge and invention spread among the industrial nations, that country which shows the greatest aptitude for forethought, planning organization, co-ordination, and co-operation of effort will lead in productiveness, economic progress, and prosperity.

Of all the factors in production, "brains" are probably the most important—to invent and develop, to foresee, to organize, plan and control, to submit existing methods continually to scientific scrutiny, to eliminate waste in the services of men and machines.

PRODUCTION FOR A MARKET

From the present point of view the emphasis is not so much on the physical processes of production as on production for a market, i.e. production with the maximum efficiency, the minimum cost per unit, and the maximum profit.

We are not so much concerned with problems of production as with production at a cost which will meet the ruling market price and leave us with a margin—the bigger the better, of course. Analysis must begin with the customer and be developed backwards. The firms which survive and prosper are those which keep in touch with public demand

and other trends, and adjust their costs of production to meet the market.

In the case of some patented articles, selling prices may have no reference to the cost of production, but the exploitation of a monopoly position is always a two-edged sword—the law of substitution is at work and sooner or later means of circumvention will be found and bring back the problem to one of all-round efficiency in production.

In mechanics, efficiency is measured by the output of work divided by the input of energy. If we consider a factory as a machine, then the economic efficiency may, for the purpose of comparison, be considered as the f.o.r. selling price of the products divided by the total cost of production. The analogy, however, must not be pressed too far. The former ratio is always less than one, but the efficiency ratio of a factory must, over a period, be greater than one or production will cease. The term total cost has been used because it is rare that operating costs cannot be reduced by installing more or better machinery, but the quantity of products that can be absorbed by the market may not be large enough to justify the expenditure. The amount of business expected is always the controlling factor in production.

The manufacturer must not, however, be hypnotized by mere volume of turnover. In seeking mass production, sight must not be lost of profits. There is such a thing—as the Americans discovered—as profitless prosperity. Over-expansion has ruined businesses. It is more important to ascertain whether the plant is concentrating on the right product in the given circumstances, and whether the output is a maximum per £1 invested in plant and employees' wages, than whether the mere physical volume of production could not be increased.

Many nice production problems arise in connection with goods in seasonal demand, involving a balancing of alternatives such as temporary closing-down of the plant, manufacture for stock, the development of new uses,

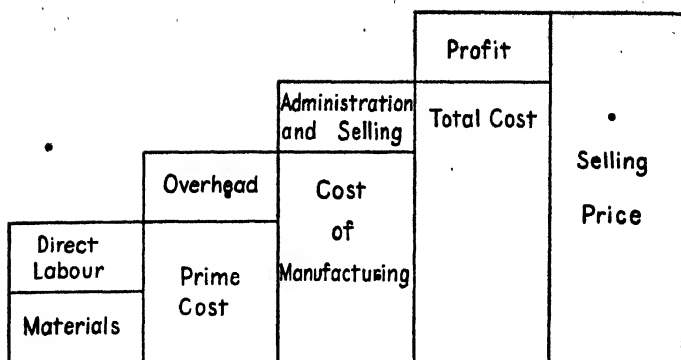
making other articles during slack periods or cultivating foreign markets. Such a situation calls for the highest business ability to organize production to give maximum long-run profits.

COSTS OF PRODUCTION

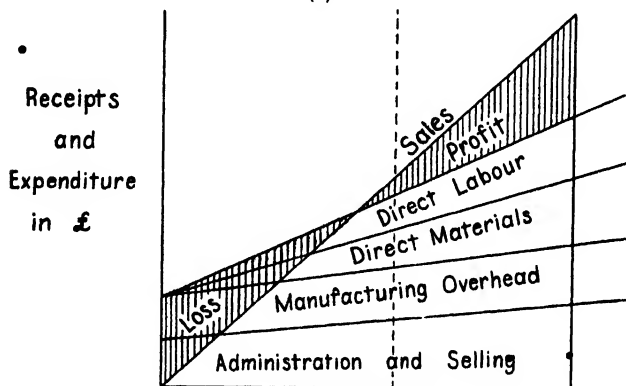
It has been observed that the requisites of production are land, capital, labour, and management, which are employed in various relative amounts in different industries. The remuneration of these four factors constitutes the cost of production. We may note that one measure of the importance of an industry is the increase in value given to the raw materials in the manufacture of the finished products. For the same value of finished goods some industries create more than nine times as much wealth as others. Highly developed machine and chemical industries show low labour charges but high investments. As operations become of greater duration and complexity, greater capital is required. The greater the quantity of machinery the lower the labour charges per unit of production, but the costs have to include charges for maintenance, depreciation, and possibility of obsolescence. The productivity of labour increases with the amount of machinery put at its disposal; this may be illustrated by the fact that its efficiency in producing wool has increased four times during the time that its efficiency in turning wool into cloth has increased over fifty times.

The constituents of production costs are costs of materials and labour, and costs of capital, power, selling, supervision, etc.; the latter costs are generally grouped under the heading of establishment charges, and are those which usually constitute the chief concern of the management. The greater the production, the less the establishment charges per unit, and the less the unit cost of manufacturing.

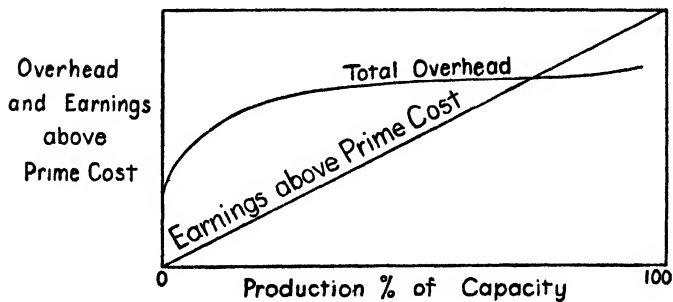
Fixed overheads continue if the plant is not running, and production must be above a certain percentage of



(a)



(b)



(c)

FIG. 10. RELATION OF OVERHEADS TO SELLING PRICE

capacity before they can all be distributed and a profit earned. This is illustrated in Fig. 10(b). It will be seen that selling goods at a lower price may, if it results in an increase in production, save rather than lose money.

In times of depression difficult problems may arise in balancing the losses due to plant lying idle against the acceptance of profitless orders, or selling some lines at a loss in order to carry a portion of the fixed overheads.

In these days of apparent saturation of many markets salesmen are not being asked to sell at higher prices, but the production engineer to reduce costs. Under severely competitive conditions for world markets, economies of production are sought and applied which in pre-War times might have been considered immaterial.

It is frequently stated that costs of production in this country are high, due to high wages; this does not mean that wages are high in themselves, but high in proportion to output. With increasing mechanization of industry the labour cost factor in production diminishes, but the materials and fuel factor tends to increase. Hence the importance of economic design and use of material and the adoption of the most efficient methods of production.

In attaining minimum production costs, however, the question of overheads is the most important, so that, in addition to the necessity for the best engineering practice, the management of an engineering works must have a full knowledge of the economic considerations under discussion, including the most economic size of enterprise, the relative costs at various scales of output, the economics of batch size, and so on.

EFFICIENT PRODUCTION

The degree of mechanization of industry is, from one point of view, an index of the industrial progress of a nation. The efficiency of labour depends on machinery which increases the volume of output per worker without fatigue and lowers the unit cost, which is of special importance

where wages are high. A more uniform product is made and at a predicted cost of manufacture.

A new type of engineer has arisen called a production engineer, having a sense of the economic process of production which he considers in relation to revenue from expenditure. He starts with the most economic method of production and lays down plant suitable for the purposes in view, but which is adaptable, with straight-line paths of progress of the product involving minimum transport times from machine to machine or department to department. He sees that materials are supplied to the workshops to keep pace with production, that the machines are fully employed and that the work is not only planned but controlled. He gives proper attention to design, standardizing the product and number of types, makes adequate use of jigs and other production auxiliaries, applies time study rationally to fix work speeds, and builds up an organization to operate without waste of material, power or time.

Efficient production involves the economic use of materials, men, machinery, and methods. It should be noted that in a modern factory all are specialists more or less, and production takes place by the co-ordination of specialists. The engagement and training of labour, the placing in jobs and the inculcation of team spirit are, therefore, of the utmost importance to the management to ensure a steady flow of production of the magnitude budgeted for. It should be remembered that the maximum individual productivity is attained when a workman is given the highest class of work within his capacity. Productivity is stimulated by arranging for the worker to have a definite amount of work to accomplish in a given time, and providing a wage incentive for him to maintain his maximum.

Efficiency in production can only be considered in relation to a given type or scale of production; for example, an efficient procedure in large-scale production might be impracticable in small-scale production, and between the

two extremes arise problems of great diversity and complexity in which the choice of the most efficient procedure may be largely a matter of experience.

JOBGING PRODUCTION

Jobbing production is the traditional form, dating from the early days of the factory system. It consists of small-scale production to meet customers' individual requirements. Jobbing production is carried on in small factories and is suited for varied work, products of special design and experimental models. It possesses considerable elasticity in operation and is capable of technical economies, if not commercial and financial ones. Continual thought must be given to the development of cheaper manipulative processes, and thus the jobbing shop obviously forms a good training ground for managerial positions as regards technical knowledge and experience. To evaluate correct estimates for work to be done, it is necessary to possess accurate knowledge of what each department or machine can do. Considerable importance attaches to the skill and ingenuity of the foreman, and the workmen must possess great manipulative ability.

BATCH OR QUANTITY PRODUCTION

This is the commonest type of production in this country, representative of the work of probably three-quarters of the engineering firms. This is understandable from the British demand for individuality combined with a diversified foreign demand. Some of the most intricate problems in production and management are involved in striking an economic balance in batch production. The most economic batch size is determined by sales demand, delivery, and stock requirements—having always a supply on hand, but not an excessive stock. Mass production may be introduced for components, combined with high quality and diversity of finished products.

The optimum lot size depends not only on the cost of manufacturing but the interest charge on the money invested in the goods and the cost of storing them until sold. (See Fig. 11.) The larger the turnover and cost of manufacturing set-up and the lower the cost per part and the cost of storage, the bigger the lot size will be. In other words, if material cost is high the economic production

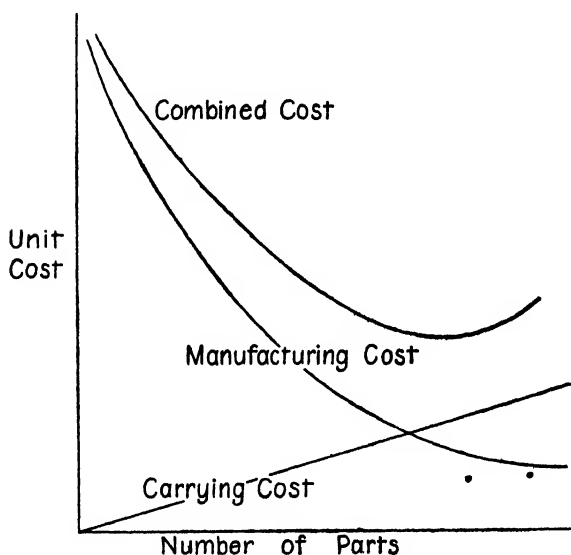


FIG. 11. OPTIMUM LOT SIZE

quantity will be small; if labour cost is high and the operation long, it will be small; if the setting-up cost is high, large batches will be economic.

To determine the manufacturing lot size for minimum total cost

Let x = lot size for minimum cost

M = average monthly requirements of the part

K = cost per part (material, labour, overhead)

U = cost of set-up plus clerical work

I = annual rate of interest, depreciation and insurance

O = minimum quantity in finished stores when new lot is started

C = storage cost per part per year

y = total cost of monthly supply M .

The manufacturing cost per part is

$$K + \frac{U}{x} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

As the quantity in stock varies from O to $O + x$ the average is $O + \frac{x}{2}$.

The average investment in finished stock is

$$\left(O + \frac{x}{2}\right) \left(K + \frac{U}{x}\right)$$

and the average charge for interest is

$$\left(O + \frac{x}{2}\right) \left(K + \frac{U}{x}\right) I \quad . \quad . \quad . \quad (2)$$

The monthly storage charge is

$$\frac{C}{12} \left(O + \frac{x}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\begin{aligned} \text{Thus} \quad y = & M \left(K + \frac{U}{x}\right) + \left(O + \frac{x}{2}\right) \left(K + \frac{U}{x}\right) \frac{I}{12} \\ & + \frac{C}{12} \left(O + \frac{x}{2}\right) \quad . \quad . \quad . \quad (4) \end{aligned}$$

Now if y is a minimum $\frac{dy}{dx} = 0$.

Expanding (4)

$$y = MK + \frac{MU}{x} + \frac{OKI}{12} + \frac{KIx}{24} + \frac{UOI}{12x} + \frac{UI}{24} + \frac{Cx}{24} + \frac{CO}{12}$$

$$\frac{dy}{dx} = -\frac{MU}{x^2} + \frac{KI}{24} - \frac{UOI}{12x^2} + \frac{C}{24} = 0$$

$$\frac{12MU + UOI}{12x^2} = \frac{KI + C}{24}$$

$$x = \sqrt{\frac{24MU + 2UOI}{KI + C}}$$

If the storage charge is small and O is neglected

$$x = \sqrt{\frac{24MU}{KI}}$$

Another method of determining optimum lot size is as follows—

Let x = the number of lots made per year

I = the interest on total raw material cost for a year

S = setting-up cost

O = output required divided by the capacity of the plant

C = cost of finished article divided by cost of raw materials

K = a constant charge on output due to labour storage and all overhead charges.

The set-up cost on the total output = Sx

Interest chargeable on material = $\frac{I}{2x} \cdot O$

Interest chargeable on finished article in storage = $\frac{I}{2x} \left\{ C(I - O) \right\}$,

Then total cost T

$$T = K + Sx + \frac{I}{2x}(O + C - OC)$$

$$\frac{dT}{dx} = S - \frac{I}{2x^2}(O + C - OS)$$

Now if T is a minimum $\frac{dT}{dx} = 0$

and
$$x = \sqrt{\frac{I}{S} \left(\frac{O + C - OS}{2} \right)}$$

The following may be taken as an example of this method.

Let the production capacity in a factory of a given article be 100,000 per annum and the sales 20,000 articles per year. Suppose further that

the value of the finished article is £1

the value of the material in it is 4s.

the labour cost (including oncosts) per article is L

the interest rate is 6 per cent

the cost of set-up is £60.

In the following table (Fig. 12) the total cost of manufacturing 20,000 articles per annum is worked out if made in 1, 2, 3, 4 and 6 lots respectively, the time to manufacture being $\frac{1}{5}$ th of a year in each case.

It will be seen that under the conditions postulated it would be most economic to make the annual output in three lots.

MASS PRODUCTION

This means continuous production with no lost time. Its basic principle involves manufacturing parts at the rate required for assembly. It involves a specially planned factory layout with the use of a good deal of one-purpose machinery and frequently of expensive jigs and fixtures. Processing and assembling are timed carefully, sometimes

Cost Items	Number of Manufacturing Lots				
	1	2	3	4	6
Labour Cost . . .	20,000 L	20,000 L	20,000 L	20,000 L	20,000 L
Set-up Cost . . .	£60	£120	£180	£240	£360
Interest on Raw Material .	$(\frac{1}{3} \times \frac{1}{3} \times 20,000 \times \frac{1}{3} \times 6\%) = £24$	£12	£8	£6	£4
Interest on Stock-in-hand .	$(\frac{2}{3} \times 20,000 \times \frac{1}{3} \times 6\%) = £480$	£240	£160	£120	£80
Total Cost . . .	£564 + 20,000 L	£372 + 20,000 L	£348 + 20,000 L	£366 + 20,000 L	£444 + 20,000 L

FIG. 12. CALCULATION INDICATING OPTIMUM LOT SIZE

to a fraction of a second. Inspection plays an important role. Continuous production involves minute subdivision and specialization of operations and machinery and the utilization of specialists.

Its principal advantage is low unit manufacturing costs from simplified operations and the increased skill of specialized workers. Other savings arise from lower cost of storage, owing to the maintenance of minimum stocks and simplified production control. Due to the careful forethought and planning required, improved quality may well accompany increased production, and waste is reduced in many directions.

It must not be thought that mass production is of recent origin. Richard Arkwright, who was born more than 200 years ago, was probably the first to appreciate fully the economic principles of machine production in the mass sense. In 1806 Brunel had a plant for the manufacture of pulley blocks on mass-production lines, and early this century it was common practice in the textile industry and in the manufacture of bicycles, watches, clocks, sewing machines, and rails and bars. In modern times, however, its scope has been considerably extended in various branches of engineering.

Mass production is, of course, impossible in the absence of large markets absorbing standard goods. On the other hand, it has introduced a new principle into marketing of supply creating demand. A good deal depends, however, on the psychology of the buying public.

The disadvantages urged against mass production include inflexibility of the specialized plant and the costliness of its replacement, sterilization of design and the loss involved during a period of change-over.

The introduction of mass-production methods involves the following steps—

1. Analysis of the various stages of manufacture, indicating the operations and types of machine required.
2. Timing the operations.

3. Determining how many machines will be required for the planned output and what load on them is expected.

4. Synchronizing the operations.

5. Planning the shop lay-out and deciding in the given circumstances whether to keep together machines of the same type or to distribute them according to the sequence of operations.

In general, the labour required in a mass-production shop is not highly skilled except in so far as it consists of skilled machine-minders.

The difference between jobbing production and mass production may be illustrated by contrasting making with manufacturing. In the former small quantities of diverse products are made by workshop methods on standard machines (centre lathes, drills) with no special layout. The men are usually skilled and paid on a time basis

In mass production large quantities of a small number of standardized parts are produced during long runs of special machines (capstans, automatics, multiple-spindle drills, milling machines, shapers, grinders). Jigs, fixtures, dies and pattern plates are widely used. The layout minimizes movement of work. Inspection by limit gauges is frequent. Production is synchronized to meet conveyor speeds. The labour is semi-skilled and is usually on some form of premium bonus payment.

The differences are obvious when considering how one or two gear wheels or connecting rods would be made as compared with large numbers of such parts. Other examples will at once suggest themselves, e.g. one flanged and dished end compared with manufacturing a lot of (say) 500, and one lever arm compared with the mass production of the same part.

Mass production yields spectacular results and meets with a good deal of publicity, far more in fact than in proportion to the amount of production that is carried out by this method. The reports of H.M. Inspector of Factories indicate that only about 8 per cent of factories in the

country employ over 100 workers, though, in this small proportion, two-thirds of the workers recorded are employed. On the other hand, heavy engineering and ship-building are the industries in which large-scale production has advanced most rapidly with over 50 per cent of the workers employed in such industries, followed by the metal trades with nearly 50 per cent of the workers employed, and light engineering trades next in proportion.

There is, in fact, evident a general tendency towards specialization of men and machines and progressive assembly of products, which partially accounts for the diminution in numbers of all-round machinists and engineers.

PLANS AND PLANNING

As the object of the manufacturer is to produce the stipulated quality at the lowest cost, and other things are subservient to this, it is necessary that he should be clear from the start on what he is going to do, and the justification of planning is the final economy which results.

Every human enterprise postulates a plan, and the success of its execution depends on the selection of suitable persons who utilize the best instruments and materials for the purpose. No plan can be formed without imagination and foresight, and no body of men can be taught to co-operate in its execution without efficient leadership. It was for this reason that the personal qualities of industrial and business managers were stressed in Book I.

Planning is a specialized function of management involving an intimate practical knowledge of the industry. It involves the establishment in detail of what is going to be done before any work is started. With regard to a new factory, the site, output, most economic size of unit, and capital expenditure must first be settled. The facilities for receiving and shipping and internal transport must be planned and the plant designed according to the needs of economic production. An essential feature is that the ground-work of production is balanced, with no weak

links or choke points to cause delay or shortage and with facilities for adaptation and expansion. The planners may then turn to a detailed analysis of manufacturing methods.

WORK OF THE PLANNING DEPARTMENT

Production planning amounts to systematization with a view to increasing output without speeding up the operatives. The essentials of planning are fairly well established as the outcome of experience and analysis. The design and specifications being worked out, the operation cards and times are established, the tools, jigs and methods fixed, and the sequence of processes routed through the plant. The lines of production flow are laid down, and, from the known operation times, a schedule of work is formulated and a time chart established which sets a rate of accomplishment for everyone concerned. The procedure for initiating work is laid down and arrangements made for supplying the workmen in advance with the materials, tools and instructions required, for the movement of work, and for the tracing of progress by reports or records. Planned schedules are made visible by the use of dispatch charts or boards.

It is apparent that planning depends on a knowledge of the capacity of departments to determine the total amount of work that may be undertaken as well as the speed of its throughput. Summarizing the constituents of production planning we have—

1. Planning the designs.
2. Planning the quality and quantity of material.
3. Planning the operations: job lay-outs, job specifications, operation instructions with times and grade of labour required.
3. Planning the tools, jigs and fixtures.
4. Planning the routes or sequence of operations.
5. Planning the internal transportation.
6. Planning the inspection at strategic points.
7. Planning the assembly.

8. Planning the schedules, preferably so that the working plan can be seen at a glance.

The planning of industrial activities is not only aimed at final economy, but the planning must not be too costly in itself. There is no one best way; each plant must work out its best procedure according to local conditions. In some plants all the operations are planned in a central office; in others the departments do a great deal of their planning themselves. The differences work out something as follows—

	Centralized Office	Departmental Planning
Product analysis	Office determines the best way of production	Foremen decide how to perform the operations
Machine analysis	Office analyses equipment and decides which to use	A plant list is kept, but no equipment analysis made
Flow of work	Office decides the operation sequence	Foreman decides which machine to operate
Rate fixing	Time of each operation settled	There may be a rate-fixing department, otherwise the foreman settles the time
Progress work	Progressing from main control board	Foremen progress operations themselves

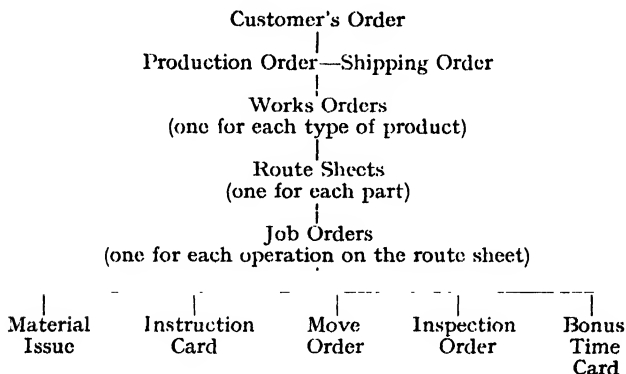
Generally speaking, for the larger type of works and where there is a tendency to continuous production centralized planning is the more efficient, but it also works very well in large repair shops.

Planning permits management by the principle of exceptions; in other words, it is only the departures from the planned production which require the attention of the executives.

PROCEDURE ON RECEIPT OF ORDER

On receipt of an order by the sales department, how is the machinery of production set in motion? The procedure will vary with the organization of the works, but

complete information of the customer's order must be issued to the manufacturing and accounting departments. The sales office will issue a production order to the production department, where works orders will be made out after careful analysis of the requirements and sent to the departments concerned with the manufacture in accordance with the schedule of work.



The planning department will fit the work into the routine, indicating a routing for manufacture. The works orders, although authorizing manufacture, may not give sufficiently detailed information for it to proceed. Job specifications are necessary for the foreman to know exactly what he is to do. We have seen in our consideration of the role of the drawing office that it can render valuable assistance at this stage, by issuing blue-prints and detailed lists covering the various components. Sometimes instruction sheets contain the requisite information for the foreman. The various job orders will be issued by the progress department, but this must not be done before the necessary materials are available. If they are not in the store they must be ordered from outside sources, or, as in the case of castings, from the foundry. Job cards as used in connection with a time recorder may be issued to enable the actual times to be recorded. The job card is written up

and issued by the job clerk against the return of a completed card, so that an operator has only one job at a time. A job card for a small shop is shown in Fig. 13. Payment of workers is made against the job card particulars.

Order No.	Machine
Job No.	Man No.
Description
.....
.....
.....
.....
.....
Job Started	Man's Rate ..
Job Finished ..	Labour Cost ..
Hours ..	Overhead ..
Next Operation	Total Cost

FIG. 13. JOB CARD FOR SMALL SHOP

Emergency or rush orders should be put through on job cards of a distinguishing colour.

There are differences of procedure according as to whether the factory is working to definite sales orders, when the job lay-out may become intricate, or to the manufacture of standardized products, when the job lay-out is standardized and production continuous.

The analysis of a job and classification of its components indicate the grade of labour to employ. Job cards when completed may constitute their own register if kept in envelopes, but for job-costing purposes they may be summarized in a Job Order Register.

Job No. Z/O 1234
(50 Gross $\frac{1}{2}$ oz. Zinc Ointment Lids, A B & Co.) •

Operation	Operator's No.	Machine No.	Monday		Tuesday		Total Hours	Rate	Wages
			On	Off	On	Off			
Stamping .									
Beading .									
Turning in .									
Counting .									
Packing .									

FIG. 14. JOB ORDER SUMMARY

ROUTING PRODUCTION

Planning of production would yield incomplete results if it did not include routing; in fact, as we have seen,

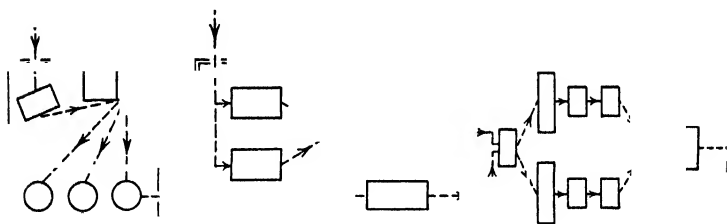


FIG. 15. DIAGRAMMATIC CHART OF ROUTE THROUGH A STRAIGHT-LINE LAY-OUT

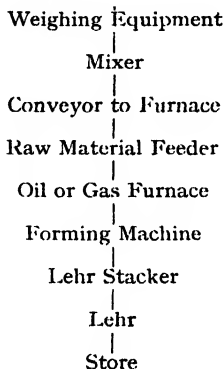
planning includes not only what is to be produced, but also where. Not only must all the operations necessary to transform the raw material into finished parts be determined, but the sequence of operations and the path of the work must be laid down, that is, where each operation is to be performed as shown in Fig. 15. Routing systems may vary from extreme simplicity to great complexity, but the fundamental principles remain the same, and the product must flow on continuously with no retracing of steps or unnecessary handling. The more highly standardized the product, the more straightforward the routing is likely, to be.

A route sheet showing the sequence in the manufacture of glass bottles is as follows—

GLASS BOTTLE FLOW SHEET

New Materials

Broken Glass



Other examples of flow sheets in continuous-production processes are the nickel production route sheet issued by the Mond Nickel Company Ltd. and the flow sheet for electric-cable manufacture issued by "The Mechanical World."

It has frequently happened that a study of the path of the product has resulted in a considerable improvement in the lay-out of the shop or works. The planning department may be assumed to have provided the best possible equipment and the best possible methods of manufacture, but the capacity of the machines and the time required will have to be determined before routing can be carried on intelligently, so that there are no pauses or congestion in production. In this connection the time element is vital if the plant is to work at full capacity.

In flow and synchronization of production a knowledge of machine capacities is vital. Some very nice problems may arise in an engineering works as to whether it is more economic to retain machine grouping on account of ease

Route cards set forth graphically the materials used, and their progress from machine operation to machine operation. In addition to showing the progress of the work through the shop, they may indicate the percentage allowance for spoilage so that the exact amount of material required may be provided. Sometimes the most economical lot size is also stated. Route cards usually contain the following columns of particulars: the nature of the operation and its number, the machine number, the grade of labour to be employed, the jigs, fixtures and tool numbers for the operation, the time allowance for setting the machine, and the time allowed for the operation itself. In some shops a record of the sequence of operations is provided in the form of an operation sheet of the form illustrated.

Part No.....	Symbol.....	Lot Size.....	Drawing No				
Operator's No.	Shop	Machine	Jigs, Fixtures Required	Set Up	Time per Piece	Time per Lot	Labour Rate
1							
2							

FIG. 16. ROUTE CARD

PRODUCTION SCHEDULE

The time factor is of vital importance in production. Plans must, therefore, be based on definite time-tables.

To secure a smooth continuous flow of production it is necessary not only to trace the path of the work, but to synchronize processes and so avoid a shortage or pressure of work in one particular section of the equipment. Particularly is this the case if the finished product of one set of machines is the raw material of another, or in assembly operations utilizing the products of different departments, together with certain components purchased complete from outside firms. In other words, production must be balanced and the plant operated as a unit.

This synchronization of processes is ensured by the scheduling of production. From a knowledge of the operation times in the various shops, the purchase time of raw materials and finished components, the time required for assembly, and so on, the various processes are put in train so that the product in the required form will be delivered as and when needed up to the stage when the finished product is ready for shipment. This scheduling involves the co-ordination of outside purchases, machine operations and assemblies so that from a knowledge of delivery times and manufacturing and assembly times a business calendar may be drawn up indicating the dates at which production reaches the specified stages. The functioning of a works depends on correct timing, and means must be devised for ensuring that the specified times and dates will be adhered to. We shall return to this question of the operation of the schedule—or, as it is sometimes called, dispatching—in Chapter V, which deals with “Progress Control.”

(2) ECONOMIC SELECTION OF MATERIALS

The economic selection of materials depends on the first cost, the ready availability and the cost of fabricating or working up. Only a complete analysis will reveal whether one kind of material or another is more economical.

An example of the balancing of the first cost against the cost of machining may be taken from the choice between

brass and steel for a given component, assuming that either metal meets practical requirements.

Using the Following Symbols	Brass Bar	Cold Rolled Steel
Cost per lb.	C_B	C_S
Number in a lot	n	n
Scrap value per lb. . . .	P_B	P_S
Weight of component . . .	$1.08 W_S$	W_S
Weight of scrap per component	$1.08 W_S$	$\frac{W_S}{n}$
Output per machine-hour .	O_B	O_S
Wages per machine-hour .	L	L
Overhead per machine-hour .	Lx	Lx
Then we have		
Metal cost per component .	$1.08W_S \left(C_B - \frac{P_B}{n} \right)$	$\left(C_S - \frac{P_S}{n} \right)$
Manufacturing cost per component	$\frac{L(1+x)}{O_B}$	$\frac{L(1+x)}{O_S}$

Extra cost of brass per component

$$= W_S \left[1.08 \left(C_B - \frac{P_B}{n} \right) - C_S + \frac{P_S}{n} \right]$$

$$= E$$

Extra cost to machine a steel component

$$= L(1+x) \left(\frac{1}{O_S} - \frac{1}{O_B} \right)$$

If we equate these costs and solve for the output of brass components

$$O_B = \frac{O_S L(1+x)}{L(1+x) - EO_S}$$

This is the hourly output of brass components which is necessary to balance the extra cost of materials. If the actual output is greater, it will pay to turn over to the dearer material.

Other examples which may arise out of the necessity to

choose between materials are the use of steel or a light alloy and the use of a metal or a moulded material such as bakelite. The acid test is, of course, will the change of material yield an overall saving?

Similar economic problems arise in making a choice between the various forms in which the material may be bought before machining operations are commenced, as, for example, between forgings and castings, ordinary castings and die castings, castings and pressed metal components. The first-mentioned may be taken as an illustration. It is obvious that the forgings will have to be purchased in larger lots than castings in order to have an economic run once the dies are set up, and this will make the carrying charges higher.

Using the Following Symbols	Castings	Forgings
Weight of component . . .	W	$f \cdot W$
Cost per lb.	C_c	C_f
Weight of turnings	$P.W.$	$p \cdot f \cdot W$
Scrap value per lb. . . .	V	V
Cost per component . . .	$WC_c - PWV$	$fWC_f - pf \cdot WV$
Number in a lot	n	N
Extra cost of dies over pattern		E_1
Interest and insurance rate per cent		I
Storage charge per year . .		S
Number of years over which initial charges must be spread		D
Number of components used in this time		X

The extra metal cost per casting is

$$W (C_c - PV - fC_f + fpV) = E_2.$$

The total carrying charge per casting is determined as follows—

The fraction of a year required to use a lot is $\frac{nD}{X}$

Therefore insurance charge per piece is $\frac{WC_0 \cdot I \cdot nD}{2X}$

and the storage charge $\frac{SnD}{2X}$

Therefore the total is $\frac{nD}{2X} (WC_0 I + S)$

Similarly for a forging the total carrying charge is

$$\frac{ND}{2X} (fWC_f I + S)$$

So that the extra carrying charge on a forging is

$$\frac{D}{2X} [N(fWC_f I + S) - n(WC_0 I + S)] = \frac{E_3}{X}$$

and the extra initial expense on a forging is $\frac{E_1}{X}$.

If we equate the extra metal cost per casting to the sum of the extra charges per forging

$$E_2 = \frac{E_1}{X} + \frac{E_3}{X}$$

or

$$X = \frac{E_1 + E_3}{E_2}$$

so that unless a greater number than this is consumed in D years, it will not pay to change over to forgings.

It will be noted that we have assumed in the above that the expense of machining a casting or a forging is the same, but, as more metal generally has to be removed from the former, this factor may have to be included.

If, however, the extra machining cost per casting is called E_4 we can re-state the above equation as follows—

$$X = \frac{E_1 + E_3}{E_2 + E_4}$$

ECONOMIC USE OF MATERIALS

Industrial waste is incidental to all manufacturing processes, the total being a factory overhead charge. Conservation and the economic use of materials are therefore of the utmost importance. The danger of waste is specially great in small parts and tools and indirect materials of all kinds. Apart from deliberate wastefulness, industrial wastes may arise in spoilage or shrinkage of materials during manufacture or storage, failure to dispose of the material removed during manufacture to the best advantage, not reclaiming by-products and not salvaging work rejected on inspection. Some rejections are inevitable in every process, but incentives and training in waste reduction will keep the number down, and the salvage committee or department can frequently effect a considerable saving by finding the reason and providing against their recurrence. The various methods of reclamation by welding, electroplating, and other forms of metal deposition, using waste for smaller components, etc., should be exhaustively studied to reduce the waste bill.

(3) WORKSHOP EQUIPMENT

The equipment of workshops can only be referred to in general terms, as it depends so largely on the industry in question. The productivity of a factory depends so obviously on the equipment that the other factors affecting production, which have been discussed above, are apt to be overlooked or to receive insufficient attention. The causes of high costs may be due quite as much to unnecessary handling charges and idle floor space and equipment as to antiquated machinery and methods. As a matter of fact, in most shops the actual production operations are carried on more efficiently than the auxiliary ones. Apart from the obvious remedy of buying the latest type of machinery, production costs can be reduced by better control, though in two equally well-organized factories the one

with the more efficient equipment will, of course, produce the more economically.

The amount of equipment necessary in a factory will depend on the quantity of goods that it has been decided to produce, the capacity of the machines, the time required for set-up, the manufacturing methods adopted, the number of shifts per day, and the number of working hours. Many more factors besides the actual equipment will affect production and costs, including the location of the machines to permit the flow of work, the provision of adequate space for the effective handling of each machine, the provision of auxiliary equipment and adequate aisles and runways. The productivity of the best equipment may be very considerably reduced if the best working conditions are not also provided. It depends, also, on the adequacy of the arrangements for storage of both raw materials and finished goods. The means of supplying power to the equipment is another important factor. Long shafts and belting cause the loss of comparatively large amounts of energy.

Plant and equipment expenditure must be laid down on broad lines so as to budget for improvements and additions as well as repairs and replacements. Equipment needs should be forecasted in view of anticipated developments. It is obviously advantageous, under competitive conditions, to keep the equipment ahead of that of rival firms in productiveness.

THE SELECTION OF EQUIPMENT

Planning is the chief characteristic of modern production technique. It is as essential in the selection of equipment as in works lay-out, in tool engineering as in the analysis of operations and determination of standards of performance. The use of equipment is, of course, with the view to reducing labour costs (although wages may be increased). If there are any cases in which hand labour

unaided by machinery is cheaper, the purchase of equipment is not, of course, justified. Let us consider an instance where the purchase of a machine costing £C is under consideration.

Let i be the rate of interest and insurance

d be the rate of depreciation

r be the rate allowed for repairs

P be the annual cost of power

and let it be assumed that the machine works 350 days per year.

Then the daily charge on the machine is

$$\frac{C(i + d + r + \dots) + P}{350}$$

With regard to labour cost let us assume the following—

	Machine Worker	Hand Worker
Daily wage	W	w
Daily output	O	o
Oncost, percentage of wages	X	x
Then manufacturing cost per unit is	$\frac{W + WX}{O}$	$\frac{w + wx}{o}$

For the installation of the machine to be advantageous, $\frac{w + wx}{o}$ must be greater than

$$\frac{W + WX}{O} + \frac{C(i + d + r + \dots) + P}{350}$$

This principle is not always fully grasped, viz. that there is no other *raison d'être* for machines than the fact that they enable more economical production. If they do not enable us to produce more economically than without them, we can with advantage employ hand processes.

FACTORS AFFECTING SELECTION

Many factors influence the selection of new equipment besides general design and first cost, such as the type and extent of work, lot sizes and degree of accuracy required. We can imagine a works manager, before buying a piece of equipment, asking himself the following questions among others—

Is the capacity sufficient for requirements?

What will be the depreciation of the machine?

What is the power consumption and the other costs of operation?

What type of labour is required to operate it and what is the labour cost?

Is it a safe machine to work?

What floor space will it occupy?

What will be the cost of repairs, and are spare parts readily obtainable?

Does it fit in with the rest of the plant?

What is the risk of obsolescence?

The efficiency of a machine is not a simple but a complex matter. It includes, of course, suitability, output, and reliability, but the critical factor is the production cost of work of the required accuracy and quality.

In the selection of workshop equipment, the problem is usually one of weighing the cost of the machine and of its operation and maintenance against the value of the work it is capable of turning out. Machines are now usually sold with guaranteed production times, which facilitates the works manager's task in this respect.

The best machine for a job is not necessarily the most accurate, the most complete, or the most costly. A far simpler machine may in the long run be more economical. It is not an easy task to pick out from a number of alternatives the machine which will give the greatest return. A knowledge of the details of an engineering business is required before one can say what is the best course to

pursue. Not only is one concerned with the best type of machine for the formulated work, but the numbers and grouping of machines bear on the problem of obtaining the most economical output. It is necessary to match the machines so that they are employed all along the line. If their productive power is out of balance, one is faced with the cost of the higher-output machines standing idle. To the average works manager a machine is merely a cog in the wheel of production, and when changing the cog the whole wheel is liable to be thrown out of balance if a long-run view is not taken.

SPECIAL v. GENERAL-PURPOSE MACHINES

A recurrent problem is the choice between a general-purpose machine and a special-purpose machine. Assuming that the work has been planned in advance and the most suitable machine selected for the job, there is a general tendency to adopt specialized machines, but it must be remembered that the most important item in job costs is overheads, which include depreciation and upkeep, and therefore it must be assumed that sufficient work is foreseen to keep the specialized machine busy. If this cannot be anticipated, the general-purpose machine has its chance. Apart from the fact that it can be purchased at shorter notice, it is more readily adapted. A special machine is usually higher in first cost, runs a greater risk of obsolescence and is more costly to maintain, so that the savings in unit manufacturing cost have to be large enough to enable it to pay for itself in a reasonably short time. The difficulty is to select the machine of maximum usefulness in the long run.

REPLACEMENT—HOW SOON WILL A MACHINE PAY FOR ITSELF?

Replacement of a machine may be necessitated by a number of events, e.g. the required output can no longer be obtained, the desired accuracy is no longer possible,

lower unit machining costs are essential, a shorter manufacturing cycle is desired to reduce investments in materials, additional repairs or rehabilitation are no longer justified, there have been advances in methods of manufacture or in production materials which the old machine cannot handle economically. It is sometimes counselled that whenever an improved design of machine is available it should be bought, but much further analysis is required before the purchase of the new machine can be justified. The reduction in manufacturing cost must be compared with the extra charges and the loss on the old machine and an estimate made of the time in which the new machine will pay for itself to see if it is reasonable in all the circumstances within the manager's knowledge.

- Let C_N be the cost of the new machine
 i, d, m be the interest, depreciation and maintenance rates per cent
 S_N be the scrap value of the new machine
 S_0 be the scrap value of the old machine
 C_0 be the book value of the old machine
 L_0 be the labour cost with overhead per unit on the old machine
 L_N be the labour cost with overhead per unit on the new machine
 A_N be the annual output of the new machine
 X be the number of years in which the new machine will pay for itself.

The annual saving is $A_N (L_0 - L_N)$;

therefore in X years this equals $A_N (L_0 - L_N) X$

The expense to be met over X years is

$$(C_N - S_N) + (C_0 - S_0) + XC_N (i + d + m + \dots)$$

Equating the above we have

$$X = \frac{(C_N - S_N) + (C_0 - S_0)}{A_N (L_0 - L_N) - C_N (i + d + m + \dots)}$$

Of course, equations and calculations cannot replace the judgment of the works manager based on practical experience, but they will provide a guide or a basis of his decision.

SELECTING BETWEEN TWO MACHINES

In selecting between two machines, either of which will do the given job from a technical point of view, a comparison will be made between the unit costs of production under the practical conditions of the shop in which they are to be used.

Call the machines 1 and 2 and

- let C represent first cost
 A represent annual output
 L represent labour cost per unit
 O represent oncost per cent
 P represent cost of annual power and supplies
 i, d, m represent interest, depreciation, maintenance rates
 X represent unit cost.

Then

$$X_1 = \frac{P_1 + (L_1 + L_1 O_1)A_1 + C_1(i_1 + d_1 + m_1 + \dots)}{A_1}$$

$$X_2 = \frac{P_2 + (L_2 + L_2 O_2)A_2 + C_2(i_2 + d_2 + m_2 + \dots)}{A_2}$$

If both machines are guaranteed as regards output and power consumption, the determination of A and P will be straightforward, but the manager's practical experience will be necessitated in regard to other factors. Other things being equal, he will, of course, choose the one with lowest overall costs.

DEVELOPMENTS IN MACHINE TOOLS

There has been a revolution recently in machine tools due to the introduction of improved cutting alloys, requiring increased power and wider range of feeds and speeds.

Sometimes the cutting tool has been ahead, sometimes the machine, but the development of tungsten carbide, which has raised cutting speeds to over 1000 feet per minute in some cases, has necessitated increased power, rigidity and strength to take full advantage of the new material. This is not the place to go into the advances in machine tool design, e.g. in balancing, bearings, forced lubrication, gearing, single-pulley drive, power-feed motions and quick-return motions, hydraulic control, and so on. Suffice it to say that there are many factors other than technical ones in selection, e.g. convenience of operation, ease of control, with a view to idle-time reduction and increased volume of output. In some machine tools hydraulic power for feeds and moving and clamping the work has been developed, but the problem is how far can it with advantage displace the more direct electrical and mechanical powers, or how will the overall cost be affected by adopting it? Are the higher first cost and perhaps upkeep offset by the range of speeds and feeds, freedom from breakdown and lower tool costs? Grinding machines have developed rapidly, e.g. plunge cutting in cylindrical grinders, and with increasingly finer limits of accuracy of work caused considerable progress in gauging and measuring instruments.

ELECTRIC DRIVES

Electric driving of machine tools has made great headway, and direct motor drive to heavy machines has been justified by experience. Its first advantage is in relation to lay-out as the position of the machine can be selected at will. The individual drive is also distinctly favourable from an aesthetic point of view.

The trend towards individual drives may, however, be overdone. It does not pay to put in a motor for operations required only at long intervals, or for which the mechanical drive is more economical.

The power of a motor driving a single machine must be the maximum that may be required at any time, but with

a grouped drive one is able to allow for the fact that all the machines never demand their maximum power at the same time. The cost per horse-power of a single motor for group drive is considerably less than that of several smaller ones for individual drive. In the case of a breakdown, however, the whole line is left standing.

HANDLING APPLIANCES

Special attention should be given to means of handling work into and out of machines. The latter sometimes appear to be designed without reference to how the work is to be handled, and lack of attention to lifting and moving appliances may risk losing all the time saved from high-speed machinery. In view of the necessity for quick handling methods, it has been suggested that the lifting tackle should be incorporated in the machine design.

A machine is idle while the operator is loading work, arranging or removing it and, as the desideratum is to keep both the man and the machine employed as fully as possible, special attention must be given to minimizing non-productive time. A record should be kept of the actual output of each machine compared with its productive capacity and the reasons for the difference analysed. A knowledge of the idle time due to handling the work is the first step towards more efficient results.

It is suggested that even greater care should be exercised in the selection of non-productive than in that of productive equipment as the speed of the former type of equipment often determines the capacity of the plant.

(4) ECONOMICS OF OPERATION

TIME AND MOTION STUDY AND LABOUR ANALYSIS

The accurate measurement of output is of great importance in every factory, both as a measure of efficiency on account of its close relation to costs, and as a basis of piece or bonus systems of wage payment.

A production order is divided according to the nature

and sequence of the work. This working plan is subdivided into processes, operations, and motions. A motion has been defined as a complex group of actions by a worker in the course of production. They are units of his labour which has to be paid for, and can only be paid for in proportion to its productivity. Hence the importance of ensuring its highest efficiency.

Motion study aims at eliminating wastefulness resulting from unnecessary, ill-directed and inefficient movements with a view to achieving maximum economy of effort. Not only does it seek to eliminate superfluous movements, but to combine and co-ordinate successive motions into a natural rhythm which is the most efficient way of doing a job. To achieve this the best possible working conditions must be provided, including suitable tools, height of work, position of workman, freedom from danger and mental strain, and so on. Motion study is a great help in the training of workmen since any job can be learned more readily if reduced to its simplest elements.

This achievement of and instruction in the most efficient way of working eliminates the mental struggle of indecision and permits higher speeds of working without additional effort.

The pioneer work of Taylor on motion study was considerably amplified by Gilbreth. The classical studies on shovellers and bricklayers were followed by investigation of many engineering operations and assembly work, resulting in a reduction in the number of movements and an increase of production without fatigue. The introduction of a photographic technique permitted the study of permanent records at leisure and enabled the workman to be shown where he was losing in motion and time. More recently the application of the high-speed camera has enabled very fast movements to be recorded and analysed. In this micro-motion study, as it is sometimes called, a chronometer is included in the picture and the operator may be photographed against a squared or sectioned

background stereoscopically or in two directions at right-angles so as to record movements in three dimensions.

In engineering tasks motion study brought to light the importance of the work place or surrounding equipment, in which there were sometimes more variations than in the movements of various workmen. The defects most frequently revealed included unsuitable tools, wrong fixtures or aids to production, wrong postures, wrong methods of handling parts or tools, wrong lighting of the work, wrong location of work or auxiliary equipment, wrong movements.

Operation analysis by motion study may result in slight modification or the adoption of new methods, but, in any case, ends in the precise specification of working methods which may be issued in the form of instruction cards for operations or assembly.

Instruction in the best ways of working includes safe working and it is found that where methods are based on scientific analysis, they are methods which result in the minimum amount of fatigue.

MEASUREMENT OF LABOUR

To pay for work on the basis of results demands some means of fixing the compensation for each unit. In the past, rate fixing has been mainly a matter of guesswork or intuitive judgment of what an efficient worker should perform. The measurement of human effort is, however, an extremely difficult problem, unlikely to be solved in a fair and accurate manner without industrial experience combined with psychological knowledge and the use of scientific method. The last factor involves experiment, measurement, and elimination of variables. In seeking to determine the number of hours in which an average man can do a given piece of work, it is first necessary to standardize the method and conditions of work and to define what is an average worker. Time must then be considered from the point of view of the workman, the equipment, and the work. Production time is only one constituent of job time;

there are also preparation time (e.g. consulting the foreman, getting tools, etc.), setting-up time, adjustment time, idle time, and so on. Idle time may not be the fault of the workman, but of the management or shop condition—transport, etc. It is unscientific and wasteful to commence the time study of a job without having fixed the method and the conditions of the job. Time study has two sides, mechanical and human, and they must be dealt with in this order.

ANALYSIS OF TIME STUDY

The successive stages of time studies are—

- (a) Analysis of work.
- (b) Standardization of methods.
- (c) Making the time study.
- (d) Analysis and criticism.
- (e) Utilization of results.

(a) ANALYSIS OF WORK. The first step is to analyse the job, split it up into its constituent elements and examine each operation critically. An overall perspective is essential, the degree of subdivision of analysis depending on whether we are concerned with jobbing, batch, or mass production. Production consists in moving as well as making, and the time spent in production operations may involve the following: preparation, making records, obtaining materials, setting up machines, loading and unloading, manipulating machines and tools, resharpening tools, gauging and delays, all in addition to the effective work. In other words, we are concerned with floor-to-floor times, not merely the period of effective production. As noted above, one of the advantages of time study is to call attention to equipment and methods and also to all sources of lost time in addition to unsatisfactory speed of working. The total manufacturing time is divided into two parts, preparation, handling and adjustment, and effective work.

Thus—

Lot Time for n Components

Set-up, handling, and adjustment.	Part sequence time multiplied by n .
-----------------------------------	--

(b) STANDARDIZATION OF METHODS. Any job consists of the following constituents: materials, equipment, working conditions, methods, and performance. Before studying performance it is necessary to see that materials, equipment and working conditions are standardized, that the quickest and best methods of performing each operation have been ascertained and unnecessary movements eliminated. Inspection requirements must be settled and the stage cleared for attention to the final variable, the performance of labour.

Personnel: Time-study Men. Too much importance cannot be attached to the personality of time- and motion-study men. They must be chosen for their tact, patience, analytical powers, judgment and accuracy as well as their training and experience. They must possess the psychologically right attitude to their job, understand the operator's attitude to work and be capable of creating interest in the work and belief in their fairness and honesty of mind. The time-study man should lend himself to no stunts. He must take care to see that the men studied are acquainted with the machine, the tools, the methods and organization of the shop, are of average ability and are in the right temper. The co-operation of the foremen and supervisors should always be sought, and also that of the trade unions.

The Worker Under Observation. It is essential to overcome the scepticism, or even worse, on the part of the workers, and obtain their co-operation. They must be thoroughly informed of what the firm proposes to do and what its aims are. The nature of overheads must be explained to them so that the operatives will understand how these will

be decreased as output is increased, whilst their own wages will go up with increased skill and proficiency. The firm must give an undertaking not to cut rates once they have been scientifically established and agreed upon by both sides, that is, unless new machines or methods are introduced, when the job will be restudied. Without confidence, a good deal of the value of time studies is vitiated. Management should remember that the old bad methods of rate guessing and cutting have been a long time a'dying!

(c) MAKING TIME STUDIES—THE INSTRUMENTS USED.

- The apparatus used in making time studies is generally the stop watch with a decimal scale. It may have one or two hands and a reversing mechanism, or two watches may be used. The watch is usually attached to a time-study board carrying the time-study sheet. The observer has to note the time of the operation under investigation or its constituents and make a record on the time sheet, an example of which is shown below—

Operation	Time in Seconds
Pick up part and place in jig	
Lower drill to part	
Drill $\frac{1}{4}$ in. hole	
Remove piece from jig . . .	
Blow out jig	
Overall time	

FIG. 17. TIME-STUDY RECORD SHEET

In metal-cutting operations, the revolutions per minute are obtained from an indicator, and the cutting speeds may be obtained by the use of a speed slide rule.

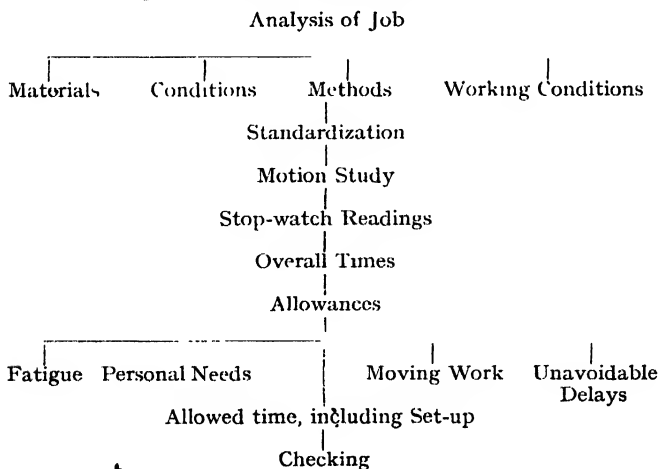
(d) ANALYSIS AND CRITICISM—ALLOWANCES. When a series of observations has been recorded the standard or average time or performance has to be ascertained. The simple arithmetic mean is usually adopted, though some prefer the modal or most frequent performance. The next

step is levelling between the performances of different operators. The time-study man must judge the work observed from the points of view of skill, effort or application, conditions and consistency and record the corrections to be made under these headings.

From such work the standard operating time can be fixed and now the question arises of the time to be allowed or task time. The experienced man will know what allowances are necessary, that they include factors for fatigue, personal needs, moving the work, unavoidable delays, etc. In a general way about 25 per cent of the operating time is allowed for these factors.

The question of set-up time has also to be considered. For long runs it might be included in the sequence piece rate, but if the set-up and preparation is lengthy or there are only a few off the operation, it obviously cannot be dealt with in this way, and a special first piece time may be allowed, or the man may have to be paid his standard time rate during this period.

Summing up the stages of time-study work, we have—



Formulae and Diagrams. The application of time studies is not limited to the part or component on which they are

performed. Standard data having been established for fundamental or characteristic work, a chart or formula may be made out from which may be read off the allowed time for jobs on which no data have been taken. The use of speed and feed charts has been known for a long time, and, if data are obtained on the maximum and minimum sizes of work done on a machine, interpolation may be made with a sense of reliability. Extrapolation is not necessarily so satisfactory. If, however, all work performed on a machine is classified and standard chucking methods, jigs, tools and other equipment used, a small number of studies will give a formula utilisable over a good range.

The formulae can, of course, be checked as and when desirable. The use of formulae and charts is not, of course, limited to machine work. They are applied to assembly, moulding, welding, drop forging, and so on.

When plotting a few actual time determinations with a view to establishing a formula, it may be found that they do not apparently lie on any simple curve. In some instances, however, a correction for some simple relationship, such as the ratio of the length to the thickness, may reduce the observations to some obvious linear relationship between time and size of work.

(e) UTILIZATION OF RESULTS--DETERMINATION OF PIECEWORK WAGES. The efficiency of linking up wages with output is apparent to all—wherever the performance of labour can be measured, it should be placed on an incentive basis of payment. Piece rates can be fixed by estimation, calculation, comparison, or time studies. Estimation is the oldest method and is still used subconsciously by many managers who prefer their experienced guesses to more scientific determinations. It has, however, led to many serious mistakes, rate cutting, and labour trouble. Calculation of piece rates from knowledge of machine performance is also unsatisfactory, as it does not take into account variations in shop conditions and materials, and omits any allowance for the human factor.

Collection and arrangement of previous results with a view to establishing piece rates on a comparative basis has its uses, but, without a large degree of standardization, comparisons may be subject to serious errors.

The only scientific method of fixing rates is by time and motion study, which should be the foundation of all incentive wage payments, guaranteed against change so long as conditions and methods remain the same. Past rate troubles have been caused not only by lack of faith in the management's intentions, but also by inefficient production knowledge and inefficient production control. Output is not and never can be a matter of workmen's energies alone, and it serves no purpose to offer employees incentives to work harder in works which are semi-paralysed by inefficiency of plant and shop conditions. Time and motion study directs attention to the latter prior to measuring the workmen's contribution.

OTHER RESULTS FROM TIME STUDY

There are many other benefits from time and motion study besides constituting the basis of rate fixing. In the opinion of some managers the determination of equipment capacities is more important. The fixing of shop capacities underlies the laying down of production schedules, and the accurate determination of delivery dates. By studying production from the standpoints of the worker, the equipment and the work, the attention of the management is directed to causes of lost time in either men or machines. Shop defects causing unnecessary work are detected and more punctual flow of material is promoted. Obsolete plant and shop methods are swept away and the management is kept informed of the economies effected by improvements. Not only is time and motion study the only rational way of determining how long jobs should take, but also the only scientific method of forecasting labour costs with precision. Time and motion studies, properly based on the principles of the psychology of work, are of great help to

foremen in the achievement of their supervisory tasks. Time studies are not something to be grafted on to the works organization; they must be an integral part of it, in which case they become a vital instrument to assist management in the economic control of production.

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CHAPTER V

PROGRESS CONTROL

IN the previous chapter we have dealt with the importance of planning, including routing and scheduling. The planning department, employing commercial sagacity to exploit engineering ingenuity, has grown up to relieve the overburdened management in large engineering firms. It aims to ensure least-cost procedure before the work is put in hand. This scientific aid to production will, however, make little headway if unsupported by progressing which is intended to ensure the planned operations being carried out. Planning will not result in achievement unless this succeeding phase of organization is efficient.

Progress means moving forward, and well indicates the function of the department. It is one of the main functions of factory administration and makes the department one of the most important units in the works organization. Production cannot proceed as a haphazard adventure without co-ordination. The time factor in production is increasingly of vital importance, and progress control has little or no foundation in the absence of prior knowledge of the time every operation takes in the plant available.

The object of the progress department is to ensure the production of the required output on time at a cost within the prescribed limits. It keeps track of all work as it goes through the factory with a view to obviating any delay and ensuring that the planned instructions and schedule are adhered to; every operation, machine section and department is kept under supervision to prevent congestion or gaps and to ensure an even flow of work, with which, of course, production is most economical. Supplies are obtained on time and work is synchronized so that hold-ups are prevented in production and assembly and the plant is maintained at full-capacity production.

Time, quantity, balance and co-ordination are the four prime-factors of progress work. Its commercial advantages in enabling the firm to keep its commitments are obvious. The question of delivery is treated on a scientific basis and goodwill fostered among customers. In addition, orders may frequently be obtained by a firm with a reputation for keeping its word over the heads of firms quoting lower prices, but with no assurance that promised deliveries will be maintained.

THE PROGRESS MANAGER

Progress work must be done whether it is organized or not, but it is unnecessary to emphasize at this stage the efficiency of specialization. In spite of the importance of the progress department, it must not, however, be unwieldy or over-staffed; the criterion of profitability must, as always, be applied. The essential feature is that the department must be capable of doing what it sets out to do. The progress manager has to see the programme through and get the best out of what is available. Obviously, he must be strong enough to enforce his instructions. It was for this reason that he was constituted a senior or major executive in our illustration of the staff and line type of organization shown on page 27. To limit the function of the progress manager to mere chasing and allow the production men to say when a piece of work will be done is a parody of management and the firm should delete the name of the department from the office door in such circumstances. It is true, of course, that co-operation is as essential a quality in a progress manager as in any other works official, but, if his authority is stultified, the work of the planning department also is rendered ineffective and wasted.

The progress manager, therefore, must not only have a strong personality, energy and push, but also a great deal of tact, for, as everyone with works experience knows, the work of co-ordinating the various and often contending

factors in the organization is all too frequently very exacting. Progress control is only achieved by the co-operation of all concerned. The manager must have a good knowledge of shop conditions and procedure or he will not be capable of bringing the "correct" pressure to bear on such diverse departments as the pattern shop, foundry, machine, fitting and assembly shops, or testing and dispatch departments, as the circumstances may demand.

As the progress manager carries the responsibility of achieving delivery by the promised date, his attention is naturally concentrated on matters which hold the possibility of delaying or limiting production, whether it be a question of supplies, production or movement of components, or lack of balance and synchronization. He must be capable of discerning potential as well as actual weak points in the production programme and obviate delays by anticipating their likelihood to occur. He must put each job on the production line at its proper time and ensure the correct sequence. Rush orders, even in well-organized works, are difficult to put through, and the progress manager must devise a suitable procedure to deal with specially urgent jobs. As a general rule, however, the issue of priority forms should be restricted and used only as a last resort. To carry out his difficult job the progress manager requires a systematic mechanism of records, including tickets, notes, summary sheets and control charts, but there is no infallible system; intelligence applied to the particular firm's conditions is more important.

PROGRESS OFFICE WORK

The progress department ensures that supplies and tools are available and then issues orders for each operation in proper datal sequence. Promptness of issue is essential; any waiting time is, of course, a direct charge against the progress manager.

The progress office is the centre of a continuous flow of documents bearing on the production position. Job layouts

are received from the planning department, delivery and shortage notes from the stores and advices that materials are ready for issue, tool completion notes from the jig and tool department, rate lists from the rate fixers, inspection notes from the inspection department, details of movement of parts from the shops, and so on.

It will be seen that progressing is far removed from haphazard chasing, though chasing is an important part of the work; in fact, it is essential if advice notes are not received at the time they are expected. As far as possible, however, the system should arrange for information to pour into the department automatically. There is only a need to chase round when production is out of step with the schedule. Progress control is impossible without an efficient organization.

Daily or more frequent reports from the various departments permit the progress manager to check off that work is proceeding as scheduled. Delay reports enable the management to fix the responsibility for broken promises as well as to decide on the action required to correct the situation.

Progress recording should synchronize with the development of production facts, constituting a kind of cinematograph film of the situation which unrolls before the eyes of the management. In fact, progress control has been described as dynamic graphics. In industries where production factors vary rapidly, recording must be expeditious and, when possible, records may with advantage be made by the use of documents that are already necessary for manufacturing purposes.

RECORDS

The records of the progress department will vary with the type of production.

The progress sheets will show details of every lot in production, the whereabouts of each job, what has been done and what remains to be done, whether the jobs are

on time or behind and, in the latter case, the causes of the loss of time, and the due dates. Orders in arrears will be thrown up in relief. In other words, the progress sheet will record every incident in the carrying out of an order from

<div style="display: flex; justify-content: space-between; border-bottom: 1px solid black; padding-bottom: 5px;"> 5 10 15 20 25 30 </div>											
PROGRESS CARD											
Order No.....						No. of Parts.....					
Operations	Dept.	Date Due	Date Done	Parts O.K.							
Sent to											
Remarks											

FIG. 18. PROGRESS CARD

the date it was received and the works instructions issued to the dispatch date.

A simple form of progress card is shown in Fig. 18. To the time scale in days along the top the progress clerk may attach tickler tabs to remind him of the date the particular operation in hand should be completed and the work passed on to the next department.

Another form of progress card has the top horizontal

scale ruled off in man-hours, the operations 1, 2, 3, etc., being inserted at the time they are rated to commence. The operations are then struck through as they are completed and, if there is divergence from schedule, a note is made of the reason. Tabs may be clipped on to the card to show when a job is held up, the colour of the tab indicating the cause.

Production data in large concerns are complex, and managers cannot keep the details in mind. To maintain control, it is necessary to have a visible system of records whereby the production information is centralized and the manager can see at a glance the stage attained by each order. Fortunately, progress records are flexible, and it is not usually difficult to adapt a system to meet the conditions of a given works. The records can be made to move at the same pace as actual production, and each order or component can be located at a glance, not only as regards its stage of progress but also its position in the factory. Attention is drawn immediately to standing or waiting orders, and priority can be given to meet the exigencies of the manufacturing position.

The proper starting-point of a production schedule is the delivery date owing to the undesirability of locking up money in materials and work in progress longer than necessary. Working backwards with a knowledge of machine capacities and the time for the receipt of raw materials, the progress department is able to determine the date on which to initiate the order.

FORMS OF PROGRESS RECORDS—GANTT CHARTS

The Gantt chart was referred to in Book I (page 132) as a mechanism for recording many management control figures, whether in connection with planning, production control, stores-keeping, cost-keeping, or wage payments. Its value was indicated as a method of presenting the facts of any situation in relation to time, the charts being easy to compile and easy to understand. They are simple

and compact and can be applied in any business irrespective of trade. In the present chapter we are concerned with the use of this form of graphic representation for the comparison of production progress with the work planned. The charts show the progressive increase in quantities in relation to a proposed schedule, and, if the anticipated progress is not being achieved, they show the reason why. Such a record of facts in relation to time indicates if the plan has fallen short, e.g. whether delivery can be made on time, fixes responsibility and compels action in regard to the situation revealed.

Gantt charts are drawn on printed or machine-ruled paper, and the record becomes merely a clerical task and the executive is able to concentrate on inquiry and action, rendering help where necessary. The manager does not need to follow the detailed progress charts, but charts of key operations or summaries. The charts emphasize that time is the most important element in production, and by keeping all the promises and plans before him the manager is able to concentrate on the most urgent points threatening delay, and if necessary give advance notice of postponed delivery. Fig. 19 shows a progress chart for work made to order.

The student will have no difficulty in seeing how such a chart could be drawn up to represent work where manufacture is continuous. The amount of work scheduled for any period may be indicated by a figure at the left of the space, thus $\left|^{20}\right|^{20}$, and the amount of work at the end of the period or up to any specified time may be shown by a figure at the right of the space.

A progress chart shows what is to be done, what is done, and what remains to be done. Gantt charts may, however, be used for many other purposes in production control. Machine records and man records indicate if time is being spent to the best advantage and, if not, why. A machine record card is illustrated in Book I (page 132), but a simple form may now be of interest (see Fig. 20).

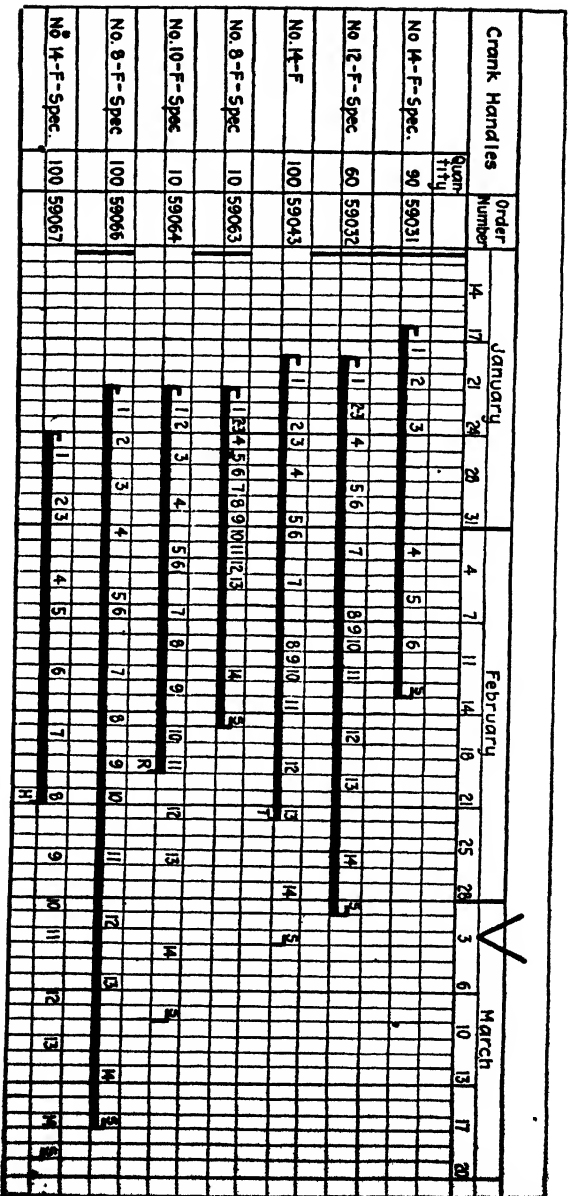


FIG. 19. A GANTT PROGRESS CHART USED IN A PLANT WHICH MANUFACTURES TO ORDER

Reproduced from "The Gantt Chart"

Productive Machinery	Percentage of Capacity Employed 50							Total Idle Hours	Causes of Idle Time						
									M	P	R	T	S	O	W
Presses									✓			✓	✓		
Milling Machines															
Planers															✓
Broaching Machines														✓	

FIG. 22. GANTT SUMMARY OF IDLENESS CHART

Alternatively, a card may be made out for each type of machinery and the first column vertically might refer to consecutive weeks. Of course, where ticks are given in the diagram actual hours would be inserted in practice.

LOAD CHARTS

A load chart shows the work to be done on uncompleted orders or work ahead not commenced yet. It is usually subdivided to refer to each class of productive machinery, the time scale being divided into working hours per week or per month. The chart gives an analysis of the situation with regard to the total hours of work ahead.

Class of Productive Machine	Number of Machines	January					February					March				
Capstans	12															
Milling Machines	8															

FIG. 23. GANTT MACHINE LOAD CHART

One may see at a glance whether some machines are over-loaded and it will be necessary to buy new ones, or whether congestion may be obviated by other means. On the other hand, it may be apparent that there is not enough

work for some machines. The load chart is also of service in quoting deliveries for future orders, what orders are needed and what kind must be refused. The chart will indicate how many men will be wanted and whether it will be necessary to work overtime or part time. In other words, the equipment, the hours of work and the operators are adjusted to the work ahead.

It is difficult to see how progress can be carried out at all without load charts which serve to indicate not only what delivery dates are practicable but also whether the maximum production capacity of the works is being used.

We have referred above to work planning and, if the orders are planned on lay-out charts, it reserves machine- and labour-time in advance for every operation through which the products have to pass. This indicates to the progress department the times to release work and to arrange for dispatching the completed products.

All unfinished orders are shown as a load ahead in days or weeks for all groups of machines or key operations.

BAR CHARTS

Although bar charts cannot be applied in so versatile a manner as Gantt charts to production control, they may be useful on occasion to record the planned time and the progress of work on a job or contract. In constructional work, for example, it may or may not be necessary to await the completion of the first stage before setting to work another group of craftsmen, and the practical requirements of the job can be set down as a series of stepped rectangles, which not only ensures that each operation shall be commenced at the correct time, but each rectangle may be filled in to indicate how far the work has proceeded at any particular date. When a firm has a number of contracts in hand, the charts indicate at a glance when each type of craftsmen will be available for commencing on the next job, by which time, of course, materials and plant will have to be got on the site.

One method of control adopted in a large automobile manufacturing concern is to prepare a summary of production details in a loose-leaf book, one page for every day of the year, indicating budgeted output, actual figures, reasons for differences and comparison of any day with the

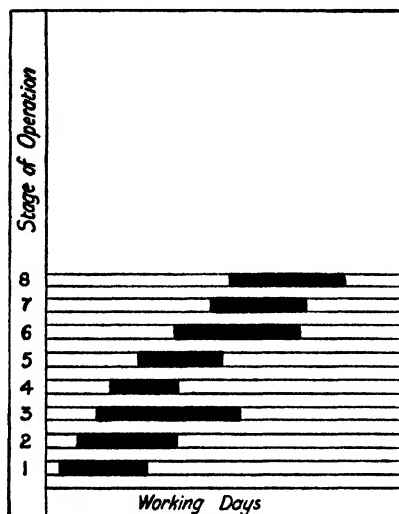


FIG. 24. BAR PROGRESS CHART

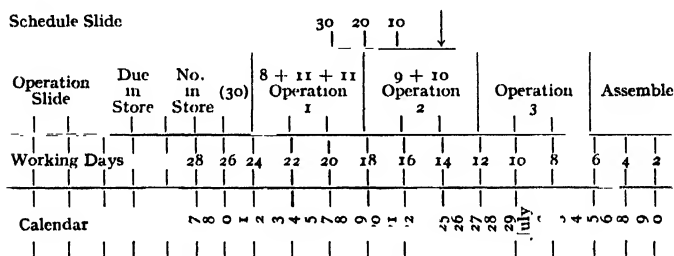
same day in the previous year. This enables the higher control to be fully conversant every morning with the previous twenty-four hours' achievement.

CONTROL BOARDS

Control boards vary according as they are employed in mass production, e.g. in textile industries and some motor-car firms, or batch production. In the former type of manufacture, the general characteristics of production are dealt with over a long period and the exception principle of control may be applied, whilst in the latter type detailed records are given over shorter periods.

A control board is a device for automatically indicating the progress of the work. It ensures that the production

facilities are put into operation progressively at the rate provided by the schedule. Control boards are mainly used for repetitive production but may, of course, be applied to batch or lot production. For a complete product a control board is rather a complex mechanism, but the principle can be illustrated by confining attention to a single unit. The device consists of movable horizontal tapes or slides as in a slide rule (see Fig. 25). Time is, of course, the horizontal reference, and the bottom slide is marked off in



Operation No. 2 is one part behind schedule.

FIG. 25. CONTROL BOARD UNIT

days of the calendar. The slide immediately above is marked off on the same scale, but in the reverse direction with working days, i.e. with its zero set at the delivery date. The third slide is marked off with the number of days required for each operation, including time needed for getting the raw material into store. The fourth or top slide governs all the acts for which the board serves as a guide. The movement of this slide, which is moved forward each day, initiates each event at the time it is scheduled to take place. On the operation strip, the number of parts completed each day is recorded. For any given operation the schedule slide is calibrated as follows: a length equal to the number of days attributed to the operation represents the number of components to be made. If work is progressing according to schedule, the total figure posted on the operation slide will correspond with the figure immediately above on the schedule slide.

The principle outlined may be extended to apply to every component of the final product by means of the complete control board, an operation slide being allotted to each component. A movable plumb-line enables the figures referring to any operation to date to be compared with the scheduled output. If desired, the board may be photographed (say) once a week for a permanent record.

JOBGING SHOP BOARDS

A simple form of control board suitable for a jobbing or repair shop is shown in Fig. 26. It may be one-sided or

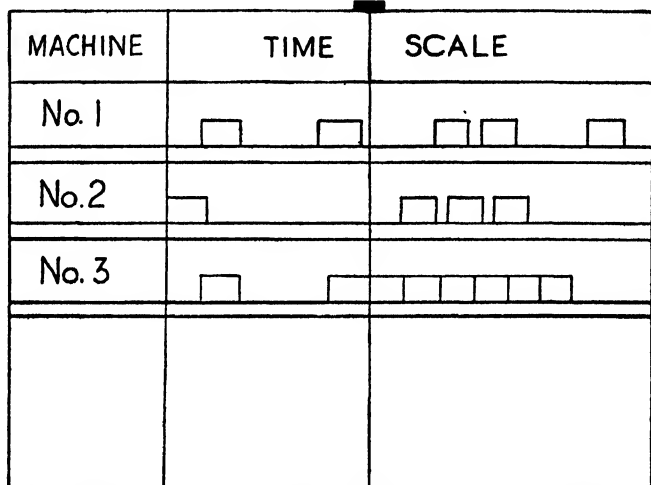
PRESS SHOP							
M/C No.1	M/C No.2	M/C No.3	M/C No.4	M/C No.5			
A							
B							
C							
D							

FIG. 26. A SIMPLE BOARD FOR A JOBBING OR REPAIR SHOP

two-sided as required. The numbers of the machines are placed along the top, and each vertical column has four pockets. The job card in the pocket A relates to the job in hand, and the card in pocket B is for the next job in order. The third pocket C contains cards relating to jobs for which materials are available, and D houses cards for which the materials are not yet available. This board is

operated by the progress clerk, and the cards or slips may be made out in duplicate or two parts marked (1) and (2).

Let us imagine that the card in B has just been placed in pocket A. The progress clerk takes the top card out of pocket C, makes out the requisition for material and sends it with the card to the foreman or group leader. When the materials are alongside the machine one part of the card is sent back to the progress man, who places it in pocket B.




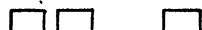



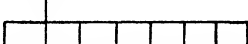
MACHINE	TIME	SCALE
No. 1		
No. 2		
No. 3		

FIG. 27. WORK CONTROL BOARD

When the job in hand is completed the job card is brought to the progress clerk, who clocks it off, the card in pocket B being then clocked on.

The board may be more extensive than the simple one illustrated; it may be twice the depth, and a number of different types of machines may be represented on it. It is, of course, a control of the order of jobs, but not of the time of the jobs. The progress clerk may, however, keep a sheet or form under the headings of Machine Number, Job in Hand, Time Started, Time Allowed, Time Finished, and

Follow-up Job. This will enable him to keep a check on whether the work is going through as desired.

An attempt may be made to connect up such a control board as mentioned above by having a time scale along the top, the machine numbers appearing in the first vertical column (see Fig. 27). A shallow rack for each machine contains the job cards, which are placed in a position to indicate when the work should commence. A plumb-line may be moved along to the time at which the board is being examined, and any machine which shows two cards to the left of the plumb-line is obviously behind schedule.

CONTROL IN A TIN-BOX WORKS

Fig. 28 shows a progress card suitable for use in metal-box making. The order refers to small tins, but all the columns may be in use for operations on large tins. The progress clerk will put the work in hand on the dates indicated, inserting the dates in red ink on the right-hand side of the columns when the operations are actually carried out. Thus the progress sheet will show at a glance what operations are to be done and when, also if they have been carried out in accordance with the schedule. The insertion of the planned dates naturally depends on a knowledge of the work before the machines, other delivery commitments, and so on.

CONTROL IN A GLASS WORKS

The actual procedure in a glass works will now be given as an illustration of progress control. On the receipt of orders the amount of work involved is expressed in man-hours and the labour cost calculated. In the Progress Control Book each process is allotted orders to the extent of its daily capacity. For each order a perforated ticket is made out, one perforated section for each process. These tickets accompany the materials in their journey through the shops. After the first process the work is inspected, and the bottom of the ticket torn off and returned to the

Customer	Order No.	Particulars	Operations							Sub-Assembly				Assembly		Despatch
			Transfer Plates	Printing	Stamping	Trimming	Beading or Swaging	Rolling	Hooking	Seaming	Soldering	Wiring	Lid-ding	Pack-ing		
Smith & Co., London	1001	500 gross Lids X 123A Bodies X 123	6	S White Gold Blue	D		B	I					✓	✓	Commence 3/8	
			7		27/7		27/2	28/2					29/2	29/2		
			18/7		K	✓		O						✓		
Legend Dates are planned dates			Nos. 6 & 7 Transfer Plates	S = solid colour	D = dome K = recess		B = Bead	I = Turn in O = Turn out						Fit lds and bodies to- to- gether		

FIG. 28. PROGRESS SHEET FOR METAL-BOX MAKING

control office by means of the pneumatic-tube system installed throughout the works. The fact that the process is completed is then recorded in the Progress Control Book. If the inspector's decision is to reject the part, a new perforated ticket is issued, but this time it is red in colour to denote that the work is behind schedule. In a similar way, the remaining portions of the ticket relating to a given piece of work continue to come in until the product arrives at the despatching department. It will be seen that the Progress Control Book shows the position at a glance with regard to every order. The system referred to also involves the use of a Promise Board, which is a simple but effective device having the following headings—

Overdue	This Week						Next Week						Ready or Wait
	M.	Tu.	W.	Th.	F.	S.	M.	Tu.	W.	Th.	F.	S.	

FIG. 29. DELIVERY PROMISE BOARD

Across the board are stretched a number of strings or wires on which small tickets referring to each order are hung in the appropriate column to show which day the work is going through. It thus gives a comprehensive picture of the loading of the plant and forms the basis of promises for future deliveries. Obviously, cards can be moved either to give priority or to make way for more urgent work (corresponding to red tickets, for example).

PROGRESS CONTROL IN AN ENGINEERING WORKS

In an engineering works engaged in batch or lot production the following system has proved effective and permits visual indication of the state of any order. The system is,

of course, based on orderly method throughout, including location of stores, drawings, jigs and fixtures, etc. To understand how the control board works, reference must first be made to material sheets and work tickets. The former are issued by the drawing office in quadruplicate, one being for the cost office. Three copies go to the progress office, where the weights are entered. From there a work ticket is issued for each machining operation, showing set-up time, working time and rates. If the materials are ready, the tickets are released to the boy in charge of the progress board. This is about fifteen yards long, having a top portion divided into monthly and then weekly sections into which small slips showing the order number, date of ordering and due date are inserted in the order the jobs fall due, so that the general delivery position is seen at a glance.

The main portion of the board consists of horizontal racks into which flat tin containers are slid, having on the face a card the colour of which indicates the urgency of the order and which contain all the work tickets appertaining thereto. Each coloured card has a summary of the operations involved. The first work ticket is taken by the boy referred to and placed in the job rack, of which one side only is accessible to him. The rack is subdivided horizontally into a number of endless belts, which accommodate the work tickets, and the lad places the ticket in the belt corresponding to the group number of the machines on which the work will be done. The other side of the job rack is accessible to girls whose duty it is to issue the work tickets to the machinists, the arrangement being such that a girl is bound to take the first ticket which appears on the endless belt. A workman states his group number and is handed the first work ticket with a job card which the girl clocks on and off in the usual way. The job card and the work ticket go to the inspector and, if correct, the ticket is passed back to the lad in charge of the progress board, who can now liberate the next work ticket on the order, striking off the completed operation on the card in front

of the container. In marking this card a suitable series of symbols shortens the clerical work.

In due course, all the operations are crossed through and all the completed work tickets are back in the container. It will be seen that this progress system permits immediate visual ascertainment of the position as regards any of the jobs in the works, of which several hundred are going through at the same time, i.e. if any job is up to schedule and, if not, how much behind and how the delivery date will be affected. The colour scheme concentrates attention where it is most needed, and the top of the board gives a picture of broken promises outstanding and the load ahead of the shops.

PRODUCTION CONTROL BY WORKS DOCUMENTS

In spite of the advantage of control boards in giving a bird's-eye picture of the progress of production, they are not, of course, absolutely essential. Use and custom render progress clerks extremely speedy at reading records, and the following is an illustration of the principle referred to above of letting the manufacturing documents of instruction serve as the progress records. The procedure again refers to an engineering works on batch or lot production.

Job orders are issued to cover each operation, giving particulars, times and rates. Four copies are made out in the progress office, each of different colour and having its own lay-out, so to speak. One is retained and three are sent to the foreman in whose section the work is to be done. The first copy gives full particulars of the materials required and the foreman sends it to the stores. When the materials are ready the storekeeper signs and sends it back to the foreman. When the latter is ready to start work he sends the copy back again. The transport man initials to the effect that he has duly received the goods, and the storekeeper sends the copy to the progress department, its presence on the file of this department showing that the work has been started. The second copy of the job order

gives particulars of the tools, jigs, gauges, etc., and the foreman sends it to the tool store. The procedure is the same as above except that when the foreman sends the tools back he receives the order cancelled. The third copy serves as a form on which the operator* books his time. It is issued in exchange for a completed order. The shop clerk clocks it on and off and sends it to the progress department. The latter attaches the fourth copy and sends them both to the inspection department. If the work is satisfactory the inspector signs the third copy and sends it back to the progress office. The work and the fourth copy are sent to the progress or finished store as the case may be, and the storeman endorses the copy and sends it back to the progress office. It will be noted that stores-issue notes and departmental notes are dispensed with.

NON-TECHNICAL USES

Progress work is concerned with more than the technical side of production. In our suggested organization chart in Chapter I, we put the labour department under the progress manager because it is as essential to get the workers into the shop as the work. As an illustration, it may be necessary for the progress man to keep a reserve of labour available for manning machine groups which are not keeping pace with the master schedule.

A further use of progress records is the calculation of actual costs to determine their coincidence with or deviation from those budgeted.

In Book I (Chapter XII), we referred to the use of progress control in office work. As an example, we may refer to the use of progress cards in connection with the receipt of inquiries and invitations to tender. Before a quotation is sent, drawings may have to be prepared, material specifications decided, labour cost estimated and completed with overhead charges, agents may have to be advised, and so on. For some reason or other, the inquiry may get held up in one department and the tender be sent in

too late and not be considered. Some firms therefore prepare progress cards for each inquiry, the departments through which it has to pass being indicated in vertical columns. At the top of the card is the time scale calibrated in days from the receipt of the inquiry. Coloured tabs may be clipped on to the tops of the cards indicating when the documents should be out of a particular department and passed on to the next. The office progress clerk looks through the cards every morning, removes those which are not up to schedule and, after making appropriate inquiries, brings them to the attention of the sales manager.

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CHAPTER VI

PURCHASING AND MATERIALS CONTROL

CONTROL OF MATERIALS AND STORES

As materials usually constitute the major portion of prime costs there is no need to emphasize the importance of the present feature of production control. The requisite of minimum overall cost of materials involves much more than buying at the lowest price. Consideration must be given to the fabricating cost and avoidance of work on defective material, avoidance of loss of interest on money tied up in stores, the prevention of accumulation of obsolete stocks, the avoidance of dislocation of schedules through lack of materials and other factors before any judgment can be passed on the overall economy of the firm's policy with regard to materials.

Though some industries depend on seasonal supplies and in others hand-to-mouth buying may be advantageous, it is usually best to take a long view with regard to the purchasing and storing of materials. Even if the purchaser has obtained materials of the required composition and properties to meet the requirements of the production department with regard to working up, and in the right quantities for the budgeted output, there are still opportunities and loop-holes for waste without adequate stores control as regards the receipt, the physical handling and storing and the issue of materials to the shops. All materials represent invested money, and the control must include the monetary point of view, not only as regards ascertaining the materials cost of each job but also securing the optimum investment of the firm's funds in this direction.

IMPORTANCE OF THE PURCHASING DEPARTMENT

One of the first acts, if not the first of all, of a manufacturing business is to purchase materials. Obviously, this

has to be done before men can be employed to work them up. As we have noted, a large proportion of a firm's expenditure flows through this channel, so that purchasing must be as efficient as production and sales. Good work in the shops may be nullified by bad purchasing, whilst, on the other hand, profits may be largely due to careful and efficient buying.

Buying is not an isolated function of the firm, but an essential part of the organization and must be carefully co-ordinated with the other departments. The purchaser must be in touch with the practical operations in the shops and understand the needs of the planning department. The average buyer is not an engineer, but he has to interpret the requirements of engineers. He is a vital factor in the progress work of the firm and in the first stages the production schedule is dependent on him. Understanding the view-point of the works, he will not require to be told that the material with the lowest first cost is not necessarily the cheapest. In fact, the frequent tragic results of cheapness need no emphasis; as previously indicated, there is hardly anything in the world which men cannot make a little worse and sell a little cheaper.

DUTIES OF THE PURCHASING DEPARTMENT

It is the duty of the purchasing department to provide adequate supplies of suitable materials at prices which are most economic in all the circumstances. The closer the association with the factory the less likely is cheapness to develop into a fetish. The purchaser should be on the production committee; in fact, it is difficult to think of this committee functioning without him. Although he will endeavour to ensure the fitness of the materials from the shops' point of view, he must not be given cast-iron instructions but must consider it his duty to suggest alternatives as regards other materials offered or other sources of supply. He must check quantities or at least be responsible therefor, and ensure that the proper inspection and tests

are made. It is the purchaser's duty to ensure that delivery is given at the due date stated in his orders, so that he is responsible for follow-up without prompting. He must keep proper records of prices, handle all invoices and discounts and co-operate as necessary with the financial department. He is also responsible with regard to returnables to suppliers, on which, without adequate attention, money is easily lost. He must know when and where to buy. From a practical knowledge of the "availability" of materials he must ensure a steady supply if such is required or at least sufficient quantities to meet demands, especially with regard to any penalty or bonus orders his firm has taken.

AUTHORITY OF THE PURCHASER

The question of the responsibility of the purchaser has already been raised and, of course, responsibility and authority go together. The authority of the purchaser frequently proves, however, a debatable subject. He must, of course, be responsible for all expenditure, that is, completely control the buying activities, but it is obvious that he cannot be allowed to buy without consulting the technical experts and engineers who have subsequently to use the materials. Should the purchaser, therefore, be under the control of the works? It is suggested that this should not be the case. Production is not the only or even the most important function of the business. Questions of finance and policy are over-ruling.

On the other hand, the purchaser should not be under the control of the commercial manager as has frequently been the case in the past, as it leads to a sense of unreality with regard to practical requirements of the shops. It is difficult to see, however, how the progress manager can completely fulfil his task if such a vital process as purchasing is beyond his control. Hence it was suggested in considering the line and staff organization in Chapter I that the purchaser should be made responsible to the chief progress officer. The vital point is, of course, to leave the

buyer a reasonably free hand, e.g. with regard to standard materials, with such measure of financial control as may be necessary in the circumstances.

• BUYER CRAFT-

The correct choice of materials is largely the job of the chief engineer and draughtsman, but when, where and how to buy and at what price are the purchaser's concern. For the present purpose we may neglect products the selling price of which does not depend on the manufacturing cost. Most engineering work is still obtained on a competitive basis, and we have seen that effective buying is an important factor in commercial success. Buyer craft, buying acumen, or flair for purchasing is not common to all men, and those who have it need to be trained and developed like any other executive, particularly in engineering firms where their effectiveness is largely dependent on their ability to co-operate with technical men.

It might be suggested that with the recent growth of ring prices there is little or no scope for buying acumen, but we have seen that low first cost is only one constituent of efficient purchasing. The buyer must see that the materials are the most suitable from his firm's point of view and keep a sharp look-out for something better or for substitutes to reduce manufacturing costs, remembering that it is the final cost which counts, not the initial cost. The purchaser is in a position to learn a good deal from the other firms' representatives who call upon him. They are able to supply him with valuable information as to why and how the results they claim may be achieved, and sooner or later the purchaser will hear of something which his own shops may adopt with advantage.

He may learn of materials which give a longer life to tools or need decreased machining time, or of machines having higher productivity or lower maintenance charges. By encouraging representatives, but without letting them waste his time, he will be kept in touch with advances in

the arts. He can then search out the facts and bring them to the notice of the factory in accordance with their merits.

As it is part of the buyer's job to seek out dependableness in suppliers, he must be dependable and reliable himself. Controversies are of no use to the purchaser's firm and must be avoided. The purchaser must appreciate that interruption of smooth flow in the shops may cost the firm many times more than paying a little more to get the goods on hand when needed. It is impossible to eliminate the risk of non-delivery, but the personality of the purchaser is probably the chief factor in ensuring that supplies are on hand when they are needed and preventing any discouraging position in the shops. In all possible ways the time of the factory must be conserved.

In order to know when to buy most advantageously the purchaser must watch the movements of the markets. Market information must be tabulated and graphed so that he may make full use of the trends and fluctuations and turn the prevailing conditions to his advantage from the point of view of both price and delivery. The purchaser applies his knowledge of the firm's probable as well as present needs, though there is rarely anything of the nature of speculative buying of engineering products. If the trend of prices is definitely upwards, contracts may be placed for a longer time ahead than usual or renewed before they have completely run out. If the price trend is downwards, the buyer may mainly be concerned with filling current needs with preference to vendors who are able to give best delivery, and machinery may only be bought if it can be used promptly. Assurance of supplies to large engineering concerns is so important that orders can only be placed with firms having adequate facilities capable of producing materials meeting exacting shop requirements, so that, in any case, the contract system is not likely to be departed from.

The buyer must not only keep accurate record of the money he is expending, but know its rate of turnover and

how much is invested in materials on hand and in process and the amount required. He must appreciate the cost of carrying stocks, when there will be less probability of over-stocking or of stores becoming obsolete. He must understand that the total expense of an order includes the interest on the money locked up till manufacture is complete and the charges entailed in handling and storing the

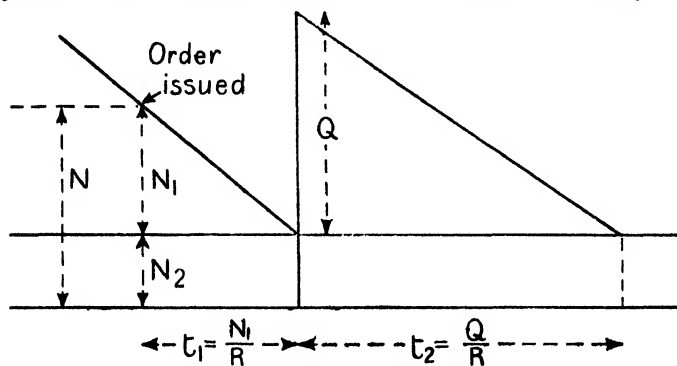


FIG. 30. OPTIMUM SIZE OF ORDER

material on the firm's premises, and that for a given rate of consumption there is an optimum size of order involving overall least-cost to the firm.

FIXING LEAST-COST PURCHASE QUANTITIES

The following is a simple mathematical analysis of this problem.

Let Q = the least-cost purchase quantity

C = the total cost of the order

C_1 = the cost per unit

C_2 = the purchase price per unit

S = the storage charge per square foot of floor space per year

A = the storage space per unit (square feet)

U = unit storage charge per year including overhead

t_1 = time to procure goods

t_2 = time to consume Q

I = interest rate

I_1 = total interest charge during time t_2

T = total expense from requisition till goods are placed in store

N = minimum number at which new order is issued

N_2 = number in reserve

$N_1 = N - N_2$

M = number in store on receipt of Q

M_1 = number on which interest is charged

R = rate of consumption per year.

Let $\frac{N}{N_1}$ = the ratio F

Then $N = FN_1 = Ft_1R$

and $N_2 = N - N_1 = t_1R(F - 1)$

$M = Q + N_2 = Q + t_1R(F - 1)$

and $M_1 = \frac{Q}{2} + N_2 = \frac{Q}{2} + t_1R(F - 1)$

Now $t_2 = \frac{Q}{R}$

Therefore the total interest charge =

$$\begin{aligned} I_1 &= M_1 C_2 I t_2 = \left[\frac{Q}{2} + t_1 R (F - 1) \right] C_2 I \frac{Q}{R} \\ &= \frac{Q^2 C_2 I}{2R} + Q t_1 (F - 1) C_2 I \end{aligned}$$

$$U = A S t_2 = A S \frac{Q}{R}$$

Therefore the total storage charge =

$$\begin{aligned} \bullet UM &\cong A S \frac{Q}{R} [Q + t_1 R (F - 1)] \\ &= \frac{A S}{R} Q^2 + Q t_1 (F - 1) A S \end{aligned}$$

Total cost of the order C

$$= T + I_1 + UM + C_2Q$$

$$= T + Q^2 \left[\frac{C_2 I}{2R} + \frac{AS}{R} \right] + Qt_1(F - 1)(C_2 I + AS) + C_2 Q$$

Let the interest factor $\frac{C_2 I}{2R} = \alpha$

the storage factor $\frac{AS}{R} = \beta$

the reserve factor $t_1(F - 1)(C_2 I + AS) = \gamma$

Then the total cost $C = T + Q^2(\alpha + \beta) + Q\gamma + C_2 Q$

Therefore $C_1 = \frac{T}{Q} + Q(\alpha + \beta) + \gamma + C_2$

$$\frac{dC_1}{dQ} = \alpha + \beta - \frac{T}{Q^2} = 0 \text{ for a minimum}$$

$$Q^2 = \frac{T}{\alpha + \beta}$$

$$Q = \sqrt{\frac{T}{\alpha + \beta}}$$

It will be noted that in this equation the amount of reserve stock does not appear.

CHECKING FACTORY COSTS

A useful function of the purchaser is to put out inquiries for parts or products made by his own firm with a view to checking the efficiency of the shops. Particularly in the case of work which the firm has not undertaken before, it may be useful to compare his own shop costs against the prices of outside makers. If his firm's consumption of a given material or component is on the increase, a problem may arise as to whether it would not be more economical to make than to buy. It might appear at first sight the

better policy to obtain everything which could be purchased at a less cost than it could be made, but this is not always the case. Such questions as the full loading of machines and the redistribution of overheads will decide the overall profitableness of buying versus making specific components, apart from such factors as the retention or displacement of workmen and other matters of policy.

The purchaser must appreciate the value of method in buying as it will assist him in many directions, not only in securing accurate checking of quantities and adequate inspection, but in sending out the correct blue-prints and specifications, in knowing who holds the requisite patterns, gauges, etc., in avoiding duplicate orders, in checking invoices, in securing the proper discounts and in avoiding penalties, and so on.

PURCHASING CONTRACTS

Reference has been made to the importance of contracts for raw materials. We considered the elements of the law of contracts in Book I (Chap. VII) and we shall revert to the tendering side of contracts in Chapter X. For the present we are concerned with the role of the purchaser in securing the best terms and protecting the interests of his firm.

The buyer must assure himself that he has reached the optimum sources of supply. It may be suggested that this is not difficult nowadays with an extensive range of trade periodicals, directories, buyers' guides, year-books and registers, but it is sometimes difficult for the buyer not to allow himself to be swayed by custom, tradition, past practice, personal acquaintance, and various wheels within wheels. His sole object should be to do the best for his firm, taking the long view. He should leave no stone unturned in analysing the market in which he is buying, and, at least in the case of the more important supplies, he should endeavour to visit the firms with which he is proposing to place a contract.

The actual terms of the contract must be scrupulously examined so that the purchaser may protect himself as regards quality and delivery, the terms of acceptance being unequivocal, and the procedure in case of rejection being clearly defined, together with the extent of the vendor's liability for replacements of material or parts subsequently found defective, the force of the guarantee to deliver at the date quoted, the terms of payment and, in fact, all points on which disputes could arise. It has been said that a buyer needs a hundred eyes. He should remember this before placing contracts—it is no use to his firm to think too late.

PURCHASING RECORDS

Reference has been made to the necessity for systematic organization of purchasing routine. Order and regularity result in work being handled expeditiously. The purchasing personnel must be kept to the minimum capable of carrying out the work, but the analytical control of purchasing information is really a question of spending to save money.

Among the records which should be kept are the Consecutive Purchase Record or Buying List on either cards or the loose-leaf system, a Comparison of Quotations Record, and a record card for each firm with which orders are placed. Other records which obviously are useful, if not essential, include—

1. The comparison of market quotations and purchase prices.
2. The total and the average value of orders over a given period.
3. The average cost of handling orders.
4. The value of the raw material in stock compared with the value of that in production.
5. The percentage of orders that need following up,
6. The average buying time.
7. The percentage of rush orders to normal orders.

8. The hold-ups due to lack of materials.
9. The number of times stock falls below minima.
10. The record of failures of materials and complaints received from the shops.
11. The record of the disposal of scrap.

In accordance with the general recommendation in this book, the total purchases should be forecast, a budget prepared, and a programme laid down. The control of purchases is also helped by a classification of expenditure accounts, to which the buyer attributes each order according to its purpose. The following expense accounts may be suggested as a guide—

1. Production supplies (subdivided if necessary).
2. Indirect materials (subdivided if necessary).
3. Machinery and equipment (subdivided if necessary).
4. Tools and loose plant.
5. Fixtures and fittings, and
6. Electric power.
7. Expenditure on buildings.
8. Stationery.

STORES AND STOREKEEPING

We have seen that the business of the purchaser is to buy materials with the lowest overall cost as and when required, and that his duties require the exercise of discrimination, vigilance and courtesy. He receives some help, in deciding when to buy, from the storekeeper, who operates on a minimum basis. The storekeeper is responsible not only for requisitioning materials on the stores list which have fallen below the budgeted reserve, but for the proper care of all materials after receipt on the firm's premises. His functions include receiving and recording, placing into store after receipt of the examiner's certificate, storing systematically and preventing deterioration, issuing only on authentic requisitions, keeping proper records of the movement of stocks and co-operating with the salvage and scrap reclamation department.

After occupying for some time the position of the Cinderella department, the stores is to-day recognized to be of great importance in production control and effective works management. The stores must be developed to the same degree of efficiency as the manufacturing department—if necessary, revolutionized to fit in with modern organization. The provision of materials as they are needed may depend on the efficiency of the stores. Delay or lost time may have a serious effect on the firm's deliveries. Efficiency does not, however, mean elaborate arrangements.

Stores represent money's worth and materials have to be accounted for as carefully and scrupulously as cash, or large losses may result. Stores and partly finished stock represent a considerable fraction of the capitalized value of the firm, on which interest charges must be taken into account to check if the capital may be more profitably employed otherwise. In addition, the cost of carrying stores safe from fire, deterioration and damage is frequently of a high order.

THE STOREKEEPER'S DUTIES

The head storekeeper is an important link in the chain of organization, and a man must have applied himself diligently to learn his job before he is fitted to take over this position of responsibility. The standing of the storekeeper has inevitably been raised by the development of cost accounting which throws a more searching light on the monetary significance of stores control. By dint of systematic and accurate storekeeping, the chief storekeeper can save the firm large sums of money. Organizing ability is an essential requirement of the storekeeper; otherwise he cannot control the multiplicity of detail work involved in the inspection and recording of receipts, the planning of the stores and the employment of the storage space to the maximum utility, the maintenance of correct maxima and minima of stock, the physical handling in and out, and the issue and record of goods as they are requisitioned.

The head storekeeper cannot walk round and do everything himself. He has to organize so that every situation requiring action is brought automatically before him, such as the falling of stocks to a point that will permit his obtaining new supplies before a dangerous shortage occurs, the hold-up in consumption of any particular stock which may threaten an accumulation of obsolete material, any threatened deterioration or depreciation of materials, any non-receipt of loanable stores or non-return of chargeable containers. The system, often very comprehensive, has to be kept going with a continuity and ease of action that will promote economy in its working.

The dependence of contracts on outside suppliers sometimes proves the weakest link in the chain of production and it requires the most careful vigilance on the part of the storekeeper to ensure that he does not get caught out with a shortage of some material which the purchaser cannot replenish in time.

The storekeeper must be vigilant by nature to prevent the numerous wastes and leakages which are liable to occur in a stores. He carries the further responsibility of seeing that all materials are booked out to the proper jobs or works orders. Reliability of the stores organization is all-important as affecting the materials element in costing. The storekeeper must also co-operate with the purchaser, as we have seen above, with the drawing office or planning department to simplify the carrying of stock, and with the shops which he is there to serve. The storekeeper has, in fact, been said to perform the non-technical work of the production manager. He is on a par with the senior shop executive men.

In many works the storekeeper is responsible to the works manager, but it is considered by some firms better policy to rid him of works control and make him responsible to either the progress manager or the accountant. It is claimed that in view of the rise of scientific costing, the latter procedure has some advantages to recommend it.

LOCATION OF STORES AND BUILDINGS

There is obviously an advantage in having the store-room situated as near as possible to that part of the factory where the materials are to be used so as to reduce handling to a minimum. The stores may be centralized or departmentalized according to the type of enterprise. It depends on the nature of the industry and the situation, size and arrangement of the other departments. In large works it is usual to find a main or central stores with sub-stores in the shops, an arrangement which is comprehensive without being cumbersome. At the main stores there may be located the purchaser's offices as well as the inspection and test departments.

Proper attention must be given to providing a suitable building, or excessive working expenses will be incurred. Whilst lack of stores space hampers operations by congestion, too much space adds to the cost. Adequate allowance for growth must, however, be made.

The storerooms must be adequately protected from theft, fire and other damage, with special constructions for housing inflammable materials if these are necessary to production. There are no objections to multi-storey buildings if efficient hoists or lifts are provided. The use of galleries is generally recommendable. Good lighting, both natural and artificial, and proper ventilation must be provided.

The stores buildings must be light and dry, have a specially good roof, and be designed with reference to the class of materials housed.

LAY-OUT

The lay-out of a stores requires careful planning with reference to the purpose for which it is to be used, so that no definite rules can be laid down as regards design. The lay-out must be simple and effective and will be governed by the four stages of handling stores, viz. receipt, inspection, storage, and issue. Before allotting space, the question of

bringing in, moving and taking out supplies, and the provision of aisles of the proper width for handling the materials must be considered. The arrangements for the receipt of goods should provide for the promptest possible handling. Unloading platforms should be at truck floor height with facilities for opening, examining, and checking, adequate space being provided to avoid congestion in case the inspector is not readily available.

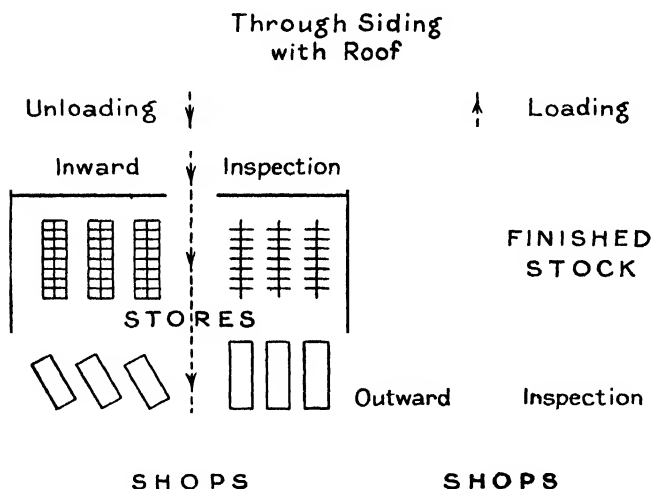


FIG. 31. STORES LAY-OUT

Appropriate materials-handling equipment for internal transport must be provided, such as overhead cranes for heavy materials, conveyors for light materials, electric trucks, bogies, and so on. If equipment is chosen to meet the needs of the materials, the risk of accidents is minimized. Standing places for idle trucks must not be overlooked.

The key-note of the lay-out should be direct accessibility, which is generally obtained by a series of aisles and sub-aisles in parallel rows. Clear gangways also add to neatness. The safety of floors, aisles, and fire passages should be ensured.

- Fig. 31 shows a suggestion for a lay-out in which the stores is adjacent to the finished stock, and the incoming wagons, which have delivered materials, may be moved on and re-loaded with finished products.

SECTIONALIZATION

Sectionalizing largely prevents overlapping and permits a more equitable division of duties and work. Fig. 32 shows how the stores of a large electrical engineering works was sectionalized.

		Raw Materials				Sundries
		Winding Store				
Receiving	Inspection	A.C. Motors	D.C. Motors	Generators	Controllers	Switch Gears

FIG. 32. SECTIONALIZED STORES

In a smaller works the sections may simply be raw-material store, work-in-progress store, finished-parts store, and also tool store.

The raw-material stores is important and requires careful control as, owing to the miscellany of materials, there is a liability to leakage, especially of very small parts. Valuable stores must be kept under lock and key. In engineering stores it is usual to have a cutting-off division with saws and a guillotine, and care must be taken to prevent the formation of an excessive number of short lengths.

The work-in-progress store is associated with, and may be under, the control of the progress department. It is exceptional from the point of view that there is no permanent allotment of space. Finished parts may be kept

ready for assembly. Where components are machined in quantities in advance of requirements they are usually put up in assembly batches.

The finished-goods store is usually under the control of the sales department, which forwards appropriate shipping instructions. It is usually run on a maximum and minimum basis. The stock in hand always appears in the Ledger Account, which will be referred to later.

The tool store issues small lots on loan. Care must be taken that tools in store are in good condition and ready for use. This store will be dealt with below in some detail.

As has been indicated, the character of materials used by the firm affects the storage arrangements. Some materials are not affected by the weather, and may be stored in open sheds, others need to be protected carefully from corrosion, such as machined castings and forgings, others again must be kept free from the access of moisture, and so on. Petrol and other inflammable stores must be kept in a separate special place. Of the various risks to which stores are exposed, i.e. fire, theft, deterioration from rusting, dirt, evaporation, the first two factors can be adequately insured against.

STORING METHODS

The position of specific stores will depend on the difficulty and frequency of handling. It should be arranged that those most frequently required are handiest. Items should be counted or weighed before storing and arranged in issuable units. Heavy stores may be placed in piles with a view to economy of space and should be cleared in rotation. A uniform method of piling should be adopted so as to increase the accuracy and speed of inspection and count. For the utmost utilization of available space a tiering truck is very convenient. Lots should be separated from each other, and the old ones cleared up before new ones are started on. Miscellaneous goods should not be stored in out-of-the-way bins or an obsolete collection may be formed,

involving a waste of space and money. It is good practice to keep the miscellaneous goods in the centre of the store.

Light articles are stored in bins or racks according to the nature of the materials to be stored. Lockers and bins designed to hold a given number of parts are often a convenience. Wooden racks are cheap, quickly made, and do not mark or bruise delicate parts. Metal racks are more durable, fire-resisting, free from splintering and breakage, and give more available space. Standard steel shelving is now provided, and unit storage areas may be used as the basis of the lay-out.

The essentials of good store practice are keeping every item in its assigned place and maintaining adequate but not elaborate records. Sources of loss are to be found in the improper diversion of materials, waste of time in locating them, and, if overlooked for a period, the possibility that they may become obsolete and unusable.

The rise and fall of stocks must be carefully noted. When a balance is struck on the bin cards after each issue it must be compared with the stated minimum with a view to preventing shortage. The fixing of maxima and minima will be dependent on business conditions, the estimated requirements, and the delivery time. The advantages of fixing minimum and maximum stocks of materials are that the risk of running out is lessened, the replenishment of stores is easier, and the working capital involved in carrying stores is kept within desirable limits. The minimum is the ordering point. The maximum is usually two or three times the minimum, but the storekeeper must use his discretion in the matter.

CLASSIFICATION AND MARKING

The importance of classification lies in ease of identification and the minimizing of time and labour spent in locating stores. It eliminates the confusion arising from different descriptions of the same materials and the use of different units of quantity. Thus a carefully thought-out system

helps to ensure accuracy in stores accounts and costs. A standard description of each item must be agreed upon and a method of coding introduced. It may be possible to adopt a code partially identifying the material designated. The code may be numerical or symbolic, which allows for enormous expansion if required. Related parts will have related numbers and be stored in close proximity, which will be an aid on issue for assembly. If the system of "unit" stores is used, sets of units involved in particular assemblies or operations will be got ready in advance.

To assist the locating of stores, points of reference or "finger posts" indicating the lay-out of the stores may well be the first part of the code numbers, a further subdivision being shown by the cards at the top of a group of bins or racks. The marking of the lay-out should be such that any intelligent person could take a copy of the code book or stores vocabulary and find his way to any item picked out at random, e.g. 1A22 might mean Aisle 1 Sub-aisle A, second rack down, second bin from the top.

The above method of classification and marking is specially suitable for details, unfinished and finished parts, and finished units. The scheme may be carried further, e.g. to link up with patterns and castings and even catalogue numbers, but bars, strips and sheets are usually stored separately. To facilitate location of bars and sheets they may be painted at one end or corner, which also is a precaution against mixing.

STOREKEEPING RECORDS

The storekeeper's figures form an important part of the firm's commitments and the data the storekeeper must have readily available include not only the quantities on hand at any time or what supplies are available but also the total required for manufacturing orders, the amounts ordered to date, received, and not yet received, and the amount allotted to jobs.

The forms used in a stores will naturally depend on the special circumstances of the organization as a whole, but the keynote should always be simplicity and convenience, and the forms should only have columns for absolutely essential information. Full use should be made of the range of colours for the immediate identification of particular forms, such, for example, as the one used to indicate a shortage of delivery or wrong materials.

It would serve no useful purpose here to go in detail into the wording of the various forms, as they must be drawn up to serve the special requirements of each firm. The essential feature with regard to any form is that it shows the indispensable facts, and no others.

The forms nearly always used, though there may be many others, include—

Purchase Requisition (Fig. 33).

Goods Inward Sheet (Fig. 34).

Summary of Goods Ordered, Received and Outstanding.

Inspection Vouchers, including excess or shortage notes and rejected materials record.

Stores Record Cards (Fig. 35). These are subject to different wording and lay-out according to whether they refer to materials, components, completed units, etc.

Bin Cards.

Shop Orders on Stores (Issue Vouchers) (Fig. 36), including foremen's vouchers.

Return to Stores Credit Notes (Fig. 37).

Completed Parts to Store Form.

Temporary Loan Form.

Stock Summaries, weekly or monthly.

The stores records constitute a running inventory and, if continually checked by sampling inspection, render a physical inventory involving temporary paralysis of the works unnecessary. Not only is this old-fashioned nightmare eliminated, but the perpetual inventory has the advantage of permitting monthly profit and loss statements and balance sheets to be drawn up.

REQUISITION FOR PURCHASE

Stores Order..... No.

Date

Please supply..... for Job No..... for Stock.....

Description	Drawing or Specification	Quantity	Code No.	Price

Required by..... Signed

FIG. 33

Storekeeper.

GOODS INWARD SHEET

Sheet No. Date Received

Advice Note	How Delivered	Supplier	Order No.	Packages	Condition	Particulars	Partial or Complete Delivery	Passed To

FIG. 34

Signed.....

Receiving Clerk.

STORES RECORD CARD

Description. Code No..... Maximum

Ordering No. Minimum (Working)
(Emergency)

Due In		Due Out		Date	Receipts		Issues		Balance in Stock
Quantity	Date	Quantity	Date		Demand No.	Quantity	Quantity	Requisition No.	

FIG. 35

SHOP ORDER ON STORES (ISSUE VOUCHER)

Section requisitioning.....

Voucher No.

Date

Reference Job or Order No.	Description	Code No.	Quantity		Posted	Price	Value
			De- manded	Sup- plied			

Signature...

FIG. 36

RETURN TO STORES CREDIT NOTE

Section returning..

Receipt No.

Date ..

Reference Job or Order No.	Description	Code No.	Why Returned	Quantity			Price	Value
				Service- able	Repair- able	Total		

Signature.....

Received.....Storekeeper.

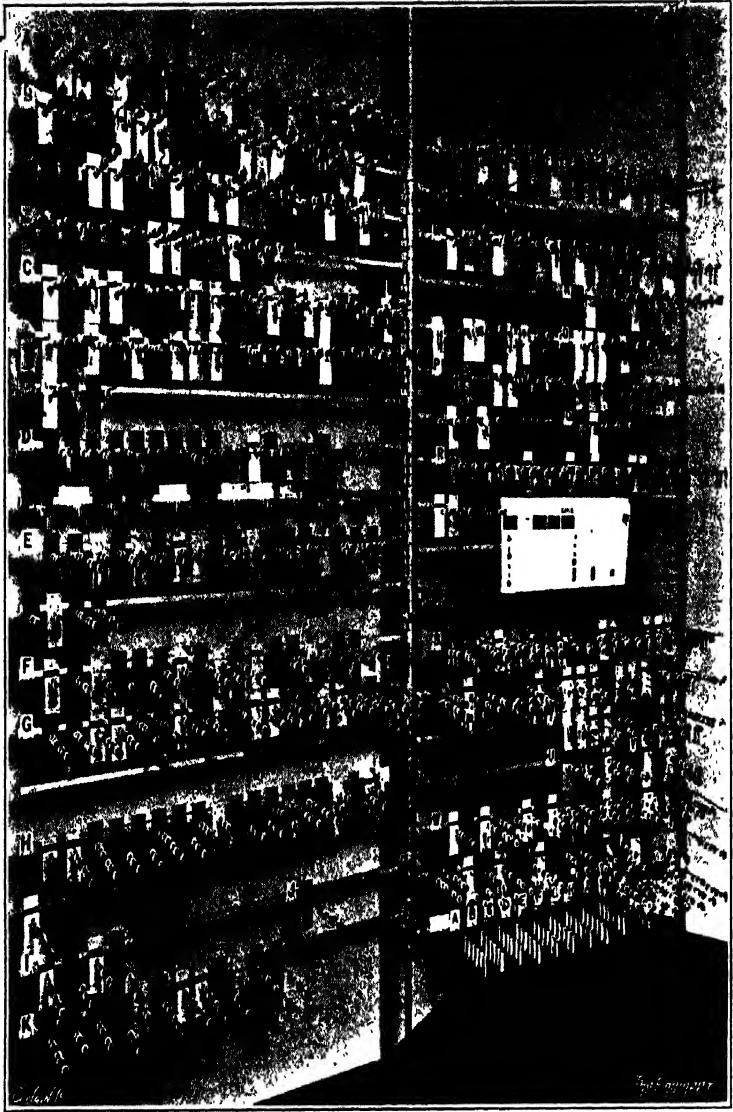
Date posted.....

FIG. 37

BIN CARDS

Objections which used to be raised against the use of bin cards were that the extra labour and expense of keeping them up were not merited, that they were a duplication of other recording and that they became dirty and unreadable, were easily lost or could be torn up and fresh ones made out.

Standard bin cards are, however, cheap and may be printed with headings such as the following: Description,



By courtesy of

FIG. 38. A PROGRESS BOARD

Colouredex, Ltd.

Attention may be called to important items or features by the use of various signals.

The great advantage is that the whole position may be seen from glancing through the system, and better control is maintained as regards both under-stocking or shortage and over-stocking of slow-moving items.

In large stores, control boards greatly economize time and require very little labour to keep up to date in regard to many thousands of items. They must be devised to meet specific conditions, but a useful method is to stick long pins with coloured heads into cards representing each item. Either different pins or the positions along a single pin at which various signals are hung will show the quantity in stock, the quantity on order, the quantity in transit, standard ordering quantity, or any other control figure which the storekeeper requires to keep continually before him. This type of control board may also be applied to progress work (see Fig. 38).

STORES CONTROL

The stores control system extends from the ordering of materials, through their actual storing and safeguarding, to their supply to the shops and assembly lines. The requisites are a clear-cut procedure and the centralization of responsibility.

A good stores procedure is a safeguard against waste of material, theft, and other losses. It involves the use of permanent records of receipt, issue, progress and final disposal so that the goods may be traced wherever they may be and in order to indicate who is responsible for their safe custody at every stage.

In every organization carelessness and misapprehension may arise, bona fide mistakes or slips occur when transferring figures from one document to another, e.g. from a requisition form to a stores record. Apart, therefore, from following the golden rule that no supplies enter or leave without documentary evidence, the storekeeper must study

the possibility of the occurrence of errors and make his own arrangements for their detection by suitable checking procedure, not only of figures but of actual quantities or weights. With regard to issues, for example, he must obtain the signature of the man accepting delivery, this signifying that he has actually received the items set out on the requisition.

The stores procedure for replenishing stock takes the form of a requisition to the purchasing department. Of course, if the storekeeper requires components which the works make, he advises the production department.

With outside purchases the vendors may send an advice note or dispatch the materials with the invoice.

When the goods arrive in the stores they should, in the first place, be signed for as received subject to count, weight, and inspection. It should be remembered that everything that comes within the company's gates must be accurately recorded in the Goods Received Book. There must be no exceptions. The materials will be entered by the storekeeper and checked against the invoice. The details generally entered are the date, order number, quantity, the name of the vendors, how delivered, condition on receipt, and inspection date. Goods Received Notes are made out and sent to the purchasing department and the inspection department. After acceptance of the goods, the storekeeper enters them up on his cards. If goods are rejected they are retained in the receiving stores pending instructions from the purchaser, and a special list of all rejected material should be kept.

Turning now to the consumption of material, issue commences with the receipt of the specification from the drawing office or planning department, either direct or through the progress department. One copy goes to the store clerk and the other to the man in charge of the actual issuing of goods, who can begin work at once. The clerk posts the details to the stores record cards, bringing down the number or quantity still available. The storesman

enters the materials out on the bin cards in the same way that the store clerk posts his records. With the use of a specification list a foreman's requisition is not required, but there are some cases in which a foreman's demand note will be necessary. In the issue of incidental stores some latitude must be allowed, but the manufacturing department concerned must be debited with them. The store clerk's copies of the specification or stores requisition is sent to the costing department and analysed for the costing books.

Materials issued in excess of the requirements of a particular job must be controlled by a Materials Returned to Stores Note, and no exchange is permitted unless accompanied by an inspector's report.

Transfer of materials from one job to another must be discouraged and all materials passed through the stores and duly credited and again debited.

The following description of a stores control system relates to a fairly large concern. On the receipt of an advice note by the purchasing department, a copy of the requisition is sent to the receiving department. On the goods being received at the central store they are checked before being signed for.

A Goods Inward Note or Goods Received Note is made out in triplicate. The first copy is sent to the purchasing department and the corresponding goods-on-order entry is cancelled. The second copy is sent to the inspection department, and the third is retained.

The inspection department makes out a form in triplicate, a copy being sent to the purchasing department and the receiving department, whilst the third copy is retained.

If the goods are accepted, the purchasing department passes the invoice and the receipts department passes the goods on to the central or shop stores requiring them, or, if they are rejected, retain them until instructions as to their disposal are received from the purchasing department.

The stores are laid out in conformity with an agreed

classification, so that the incoming goods can at once be placed in the correct bin, rack or stack, even by an intelligent stranger once he is in possession of the code or vocabulary as it is sometimes called. In addition to the consignment being entered on the bin card, the keeping of a stores record by the storeman gives an independent check.

No issue from the stores is made without a proper authorization. The requisition is made out in triplicate, a copy being sent to the stores, which retains it for recording purposes, a second to the foreman with the goods, and the third copy being retained by the department issuing the requisition. The first and second copies finally come together in the costing department.

For consumable stores or small items the foreman makes out a voucher in duplicate, one copy going to the stores and the other copy being retained, but ultimately the two copies come together again in the costing department.

For any surplus material returned to the stores a credit slip printed in red is made out permitting the accurate booking of such transactions in a similar manner to that of material requisitions.

The system outlined permits a triple check on stores, viz. the comparison of bin cards, the storeman's record and the Stores Ledger. The stores organization is duplex, the clerical and the actual handling sides being distinct but correlated.

If a firm makes its own raw material, for example, in a separate works, store control involves the ordering of material in anticipation of demand, consideration being given to the period of manufacture of the raw material as well as its further fabrication and elaboration before delivery to customers. A factory programme being established, the material must be ordered regularly and requisitions modified by the storeman to meet the developing market demand. He has, therefore, to give his attention to the rate at which material is being taken out of his stock and adjust his orders to maintain his minima. It will be

seen that, if the raw material is prepared in a variety of forms and sizes, a difficult problem of stores control is presented.

THE STORES LEDGER

The Stores Ledger is intended to catch up the total expenditure on stores over a trading period and indicate the value of stores on hand at the conclusion.

On the debit side are posted incoming stores either as received or as shop returns to store, and on the credit are

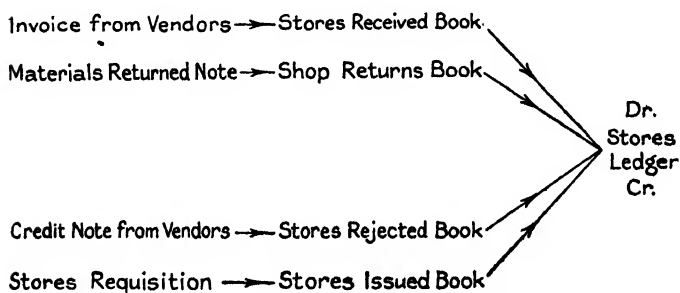


FIG. 39. STORES LEDGER ENTRIES

stores rejected and stores issued on requisitions. Each side of the ledger may be ruled as follows —

Date. Reference. Quantity. Price. Value.

The relation between various forms and books used in connection with the compilation of the Stores Ledger is shown in the diagram above.

The ledger is a kind of stores balance sheet, and the use it makes of stores values will be easily distinguished from that made by the job costing department. It will be obvious that a store requisition may refer to a number of materials, so that for the present purpose it may be helpful to make out allocation sheets to which the various kinds of materials are posted from the requisitions, and similarly with any surplus materials returned to the stores.

The effectiveness of the stores accounts will depend on the number of separate accounts in the Stores Ledger.

The balance of the Stores Ledger gives a perpetual inventory value independent of stock-taking. The figures must reconcile with the financial accounts, and, if finished goods are kept in the store, the stock on hand at the closing periods must agree with the Finished Stock Account in the General Ledger. The Stores Ledger must not be kept by the storekeeper but in the cost office or accounts department as it furnishes a check on his records; in fact, the storekeeper may not know the value figures at all. Some firms object to the storekeeper having knowledge of prices as, if information on cost leaks out, the effectiveness of control may be weakened. Others consider that the storekeeper appreciates his responsibilities better when he has some knowledge of the money values under his control.

VALUATION OF STORES

The valuation of stores in relation to cost and market values raises some interesting points, and is a subject on which there is some difference of opinion. If materials are charged at the cost price of the quantities in stock the figures show the actual cost of manufacture and do not interfere with balancing the Stores Account in money value. On the other hand, when it is necessary to charge a job with materials it may be that prices have fallen and the manufacturer will stand a good chance of losing a contract in competition with others who have access to the market. The remedy is obviously not to allow stocks to accumulate in a period of falling prices.

On the whole, it seems more practical to make use of the market price of stores, the prices of materials being revised accordingly. Discrepancies occur, however, in the Stores Account as a whole, which represent a profit or a loss due to fluctuation, but this method affords a sounder basis for estimating for competitive purposes, as it deals with actual values rather than former values. A distinction is drawn between profit or loss due to price changes or speculation and that due to manufacturing. This method of charging

stores is equivalent to treating the stores as a separate operating department.

The prices used for stock-taking purposes should be the average of those of the remaining stock or the market price, whichever is lower. In a falling market some provision may prudently be made for depreciation, but in a rising market the value of stores should not be written up.

TOOL-ROOM STORES

The tool shop and stores should be planned according to the size and work of the factory. It is a subject which has received a large amount of thought and consideration, and in the case of a plant being newly laid down, there will be no difficulty in selecting an approved plan as a basis for the lay-out. In a large works there may be a main tool store with sub-stores in each department.

Before considering arrangements for storage, careful consideration must be given to classification of tools, jigs, and fixtures, which in machine shops is highly developed. Classification greatly facilitates identification of tools, simplifies the work of storage, and conduces to brevity of records, in this way effecting considerable economy of time and trouble.

The arrangements for tool storage, whether in bins, racks, cabinets, or boxes, must occupy a minimum space and yet be adaptable and flexible so as to permit of expansion. Metal racks have advantages in this direction. Uniformity is desirable up to a point. Accessibility and ease of removal are essential. From this point of view steel equipment may save time. Small consumable tools, such as files and grinding wheels, may be stored in trays. Handy bins are designed to hold, for example, drills and reamers of all sizes. In some works tools for each class of machine are stored in separate compartments.

All tools, jigs, and fixtures, when not in use, must be kept in their allotted place and the system of recording receipt and issue should be such as to constitute a perpetual inventory.

The tools may be recorded on stock cards kept on a maximum and minimum basis. The chief storekeeper must exercise discretion in ordering tools according to the demand and the showing of his records, and keep the stock within reasonable limits, but no tool will be passed into store without inspection.

The tool store is a lending department; the tools may be recalled at any time should circumstances demand it.

The storeman has to know not only how many are in store, but also how many are in the shops and where.

The method of issuing tools is of importance in preventing loss and saving inventory time. Tools may only be issued against a requisition form signed by a duly authorized official, or against a tool list sent to the tool room by the planning department, but in any case the responsibility for return must be indubitably fixed. It is generally placed on the operator to whom the tools are issued, who acknowledges receipt either by signature or the use of a token. An old tool can only be replaced when it is returned to the store. Sometimes a double-check system is employed, the issue of the tool being indicated under the tool number and under the number of the workman who is using it.

Under the single-check system each workman is handed a number of metal tags bearing his number and he gives up one for each tool issued. The storeman places it in the tool compartment to indicate the location of the tool in the shop, but there is no information available as to the tools that are in the workman's possession.

The double-check system was devised to indicate what tools had been issued to each workman. He gives up two tags for each tool, one being placed in the tool rack and the other on a hook bearing the workman's number. To obviate the use of large numbers of tags, figures on the back indicate the number of tools which each tag covers.

Tags are rather cumbersome and cardboard checks may be used in two parts, both halves being destroyed when the

workman returns the tool. Slips of paper are perhaps preferable to both tags and cardboard, as they can be slipped into card files. Another advantage is that a number of copies can be made at a single writing, three copies being ample. The first is filed under the workman's number, the second under the tool symbol, and the third handed to the workman; when this third copy is returned, number one would be destroyed at once and number two at leisure.

Drills, taps and other small tools may be requisitioned in numbers by a foreman, who holds a small stock in his desk and can keep an eye on their consumption to prevent carelessness or extravagance and to ensure their economical distribution. On return to the store after use, tools must be inspected so that defective ones may be repaired or reconditioned before they are put back in store and become available for immediate reissue. This inspection on return results in economy in use. For minor repairs a tool maker may be located in the stores and equipped with a drill grinder and a cutter grinder among other tools.

FOUNDRY STORES

A pattern stores presents some interesting problems, including that of whether to store according to size or in batches for which the patterns are required. The former method saves space and the locating of specific numbers is easier. It requires closer attention, however, when a change in design occurs to see that each relevant pattern is altered. The latter method simplifies sorting out as it is simple to withdraw a complete set. The clearance of obsolete patterns is facilitated, and it is easier to see if a set is in good condition.

In any case, a card index should be kept with a recording system which is independent of the man who keeps the index.

CHAPTER VII

FACTORY COSTING

It is necessary for a works manager to be an expert in the mechanical processes his work involves, and possess the ability to direct and control men, but these abilities do not complete the requisites for the successful performance of his function. We have already noted in Book I (Chapter XIII) that he must also possess a cost sense, or ability to analyse the cost of operations, materials and expenses under his control with a view to carrying out manufacture at the minimum cost. This does not mean that an engineer must acquire an expert knowledge of accountancy. Accountants extract and present figures which form the background of economic production, covering a wider ground than the origin and incidence of manufacturing costs. The works manager must, however, consider it part of his job not only to control the direct costs of production but to understand, scrutinize, and be responsible for shop expenses and their incidence. He is engaged to produce at or below a pre-determined cost, or in the absence of a budgeted cost at the minimum practicable cost. A costing system must be adapted to suit the nature of the works it deals with, and this can only be achieved by the fullest collaboration between the works manager and the accounting department. The former must understand that the accountant's passion for detail is not fussiness, but arises from his knowledge that, unless cost accounts are accurate, they are of no use at all, and that collaboration will greatly assist the engineer's task of economic production.

IMPORTANCE OF COST ACCOUNTING

Costing is a management mechanism which portrays in money values the activities of the firm. Scientific costing

cannot be achieved with haphazard factory methods, and it is significant to observe that, when reorganization of a firm proves necessary, one of the first steps is to appoint a cost accountant in control. The co-operation of the accountant should be welcomed by the works executive as his aim is to increase efficiency by indicating waste and leakage of materials and time and uneconomic factory expenses.

In the past, accounting was limited to the statement of money transactions and stock-taking, the results being set forth in the Trading and Profit and Loss Accounts, but leakages of material and wasted labour were not revealed. Competition, however, rendered imperative the ascertainment of costs as the starting-point of investigation of their possible reduction. The significance and importance of cost accounting were, however, only slowly recognized, as the Ministry of Reconstruction after the war was forced to state that only 5 per cent of British manufacturers knew their costs. Since then the science of cost accounting has developed rapidly and reached a high degree of refinement in what is admittedly difficult work. Even to-day accountants would hesitate to claim to say what the exact cost of an article is where overheads are concerned.

Cost accounting is, however, a vital factor in scientific management. Although the costing department is itself an overhead expense, and like every other expense must justify itself by yielding a revenue, so important is its work in improving productive efficiency and enabling a complete control of expenses to be exercised that it is inconceivable for a firm to exist without a costing system.

COST ACCOUNTS IN BATCH AND CONTINUOUS PRODUCTION

The usual job-costing method aims at collecting the costs of a completed batch of articles under the headings of material, labour, and overheads, inquiries being subsequently made to discover the reason for abnormalities but

seldom yielding anything more than a crop of excuses. In job costing, however, labour and materials can be charged to a definite order, whereas in continuous manufacture the cost of material and labour can usually only be charged to a particular stage of production. Reports advise the management of the yield of each process, and the unit cost per process is calculated. Sectionalization is necessary, and it is usually advantageous in cost control to charge each succeeding department with the total cost of goods sent to it.

It should be noted that in a number of industries uniform systems of costing have been prepared which permit comparison between different firms within the industry, cf. the systems of the Federation of Master Printers and the British Iron and Steel Federation.

ELEMENTS OF COST

The elements of cost are direct and indirect. Direct costs are those which can be separated for each piece of work, viz. the materials directly used in the job and the labour directly employed in production. The indirect costs are all the other expenses which cannot be definitely charged to each piece of work, though an attempt has to be made to load the cost of each piece with its due and proper share. Indirect costs include indirect material, indirect labour (used in the service of the shops), and all the other charges involved in running the works and offices, selling the products and general administrative services.

Summarizing the cost elements to be recovered in the selling price, we have—

Direct Materials Expenditure	}	Prime	}	Factory		
Direct Labour Expenditure						
Factory Expense Charges		Cost		Cost	Total	Selling Price
Selling Charges					Cost	
Administrative Charges						
Profit						

or, simply illustrated in a diagrammatic form, the constituents of the selling price are as follows—

Materials Labour Factory Overhead Firm's Overhead Profit

Factory expenses include all other charges applicable to production other than direct materials and labour. An indication of the content of factory expenses and their subdivision may be given roughly as follows—

Indirect Materials	Indirect Labour in	Miscellaneous Expenses	
		Standing Charges	General Charges
Shop Supplies Tools, Patterns Coal and Coke Gas	Supervision Inspection Stores Tool Room Clerks Transport Time Office Drawing Office	Rent Rates Depreciation Insurance	Management Efficiency Department Employer's Liability Welfare Department Repairs and Renewals Power Lighting Cost Keeping Stationery Patents

Selling expenses include all costs incurred in selling the products, e.g. selling organization, packing, delivery, publicity and propaganda, exhibition charges, etc.

Administrative expenses comprise the cost of running the financial side of the business, directors' remuneration, and so on.

These general overheads, as they are called, will not be considered in further detail here, but we may pause to note that the effect of high efficiency on the part of the works manager in achieving low factory costs may be stultified in the absence of equally efficient control of the expense of the functions of the firm other than production.

The determination of selling costs is, however, as important as that of production costs to maintain an efficient business unit. Admittedly, distribution of selling expense over the various goods is difficult, and usually the cost of selling is taken as a percentage of the production cost, but this is unjust. A compromise may be made by classifying the products in groups in endeavouring to establish selling costs as the expenses may be more readily classified according to lines of work.

ALLOCATION OF DIRECT COSTS

We have seen that direct materials appear in the finished product less the wastage caused by machining away, scrap, etc. Their cost control depends on efficient stores accounting. No stores should be issued into the shops without a duly authorized written order as previously indicated; this authorization may be a complete specification of materials from the drawing office, which is sent on to the cost office for charging to the particular job or order, or it may be a requisition from the shops, properly certified, and indicating the job, so that the materials may be transferred to the job cost sheet. Materials found to be in excess of requirements should be returned to the stores and a credit note issued and passed to the costing department. An abstract of materials cost should be sent weekly or a shorter interval to the works manager to keep him advised of expenditure and to enable him to check progress against estimates.

Cost control of direct labour involves the expression or conversion of all labour charges in terms of time. We have referred to time studies in a previous chapter. Knowing how long a job should take is the basis of control of the labour cost of a job. The various systems of wage payment by results are directed to keeping the direct labour cost within an allowed figure. The methods of time recording and time checking by means of job cards and time clocks have been referred to above. The time spent on every

operation in a job is converted into money value by the wages clerk and transferred to the job cost sheet.

All work on a product is abstracted and booked to one order number. In large companies a tabulating machine may be indispensable for such purposes. The ascertainment of direct labour cost depends, therefore, on efficient time accounting and may be considered a relatively simple matter if modern methods are employed. It is not possible, of course, to obtain all labour charges expressed against time, but, whenever it is economically possible to charge direct, it is advisable to do so.

OVERHEADS OR ONCOSTS

The more difficult problems in the control of manufacturing operations in terms of money arise with regard to oncosts or overheads. What contribution shall each product, job or class of product make to the overheads? Incorrect distribution may make a product appear remunerative when in reality the reverse is the case.

From our present point of view we are more concerned with overhead costs as a factor of business economics than as a problem in accountancy. Management not only wants to know what the overhead costs are and how they should be allocated, but also to understand how they behave when the production varies, so as to run the plant at the most economic load level.

As no two works are alike in arrangement, organization, etc., the factors determining the choice of the particular method to be adopted must be subjected to close scrutiny and study. The prime object of the method adopted is to ensure that the total expense is fully absorbed and the incidence of expenses is correct.

It should be noted that increasing overhead cost is not necessarily a mark of inefficiency. In highly mechanized mass production, productive labour costs are usually low and oncosts high, and as production costs decline selling costs may rise.

. . . ALLOCATION OF OVERHEAD EXPENSES

The methods of allocation of oncosts or absorption of collective charges in common use may be divided as follows—

(I) BY PERCENTAGE

(a) *By a percentage added to the combined total costs of direct material and labour (prime cost).* It must be remembered, however, that the value of the material or the pay of the workmen may have little relation to the indirect expense from job to job.

(b) *By a percentage of direct productive labour.* The percentage is the ratio of the total charges to the total labour cost of the department taken over a reasonable period. This method is reasonably accurate in the absence of special conditions and has the advantage of simplicity. It distinguishes between machines, but is strictly accurate only when the machines and work produced are uniform.

(c) *By a differential percentage added to material and labour.* Objections to the use of a percentage on material include the possibility of fluctuations in price of materials and the differences which exist in price and weight between the various classes of materials. In some classes of engineering work, however, the addition of a percentage (e.g. 120) on the direct labour for general expenses and a smaller percentage (e.g. 30) on materials to cover the cost of handling and storage has been found to be a reasonably accurate distribution of overheads and is preferred to some of the more scientific methods referred to below.

(2) BY HOURLY RATE

(a) *Man-hour rate.* The total charges are divided by the total productive man-hours of the department and allocated pro rata to the number of man-hours on each job.

The method takes no account of the use of different types of equipment, though it covers variations in the rates of pay. It shows up the effect of employing cheaper labour

over a long time. The method is not accurate if diversified products are made, but finds an application in fitting and erecting shops.

(b) *By machine-hour rate.* The total charges are apportioned to the individual machine tools and divided by the number of hours each machine tool operates. It takes into account variations in size and type of equipment, size and type of product and rates of pay. In some cases it may not be practicable to carry the division of expenses down to individual machines, and an hourly rate for a group of machines may be utilized. In spreading the total oncost of the department over the machines, the whole of the expense necessary to keep the shop in operation must be caught up and distributed in accordance with the burden created by each machine.

Later in this chapter we refer to a Machinery and Plant Register for recording depreciation and maintenance charges. This register may also be used for recording the share of each machine of the other oncosts of the shop, for example, under the following headings—

Building or Housing Expenses—rent, rates, taxes, insurance, heating, lighting.

Power Expenses—metered separately if possible.

Supervision.

Indirect Labour.

Supplies.

Miscellaneous.

The total divided by the production hours is applied for every hour the machine spends on a given job, that is, added on to the direct labour and material cost.

Where, however, the proportion of direct labour cost is small compared with that of materials or operating the machines the labour cost may be included in the overhead, e.g. in the case of a man operating a number of automatics, the labour cost is almost constant per unit of production and is included in the machine rate, which is added to the materials cost.

It will be noted that an increase in the volume of work will decrease the actual machine-hour rate and a fall in volume will increase the rate, and we are faced with over-recovery and under-recovery respectively. The subject of idleness oncost will be referred to below.

(c) *A combination of (a) and (b).* The man-hour method brings out the effect of employing differently rated labour and the machine-hour method the effect of using differently rated machines, and it might be thought that a combination might possess the advantages of both, but this is rarely practicable. It is better to sectionalize and use the method best adapted to the work of each section, adding, if necessary, a general hourly rate to catch up expenses which cannot be allocated to any section but is shared by all.

(3) BY UNIT RATE

Tonnage or other unit. The total charges are divided by the total output. This method is applicable only to shops which manufacture one type or class of product.

As oncost loading is fixed in advance of a given operating period, charges and production have to be forecasted, and the use of the words total charges, total output and total productive hours refers to either forecasted figures or normal rates. Such figures are established by study and experience. Normal rates can only be determined from a period covering seasonal or cyclical fluctuations, and then there will be a difference in each period from the actual expense. This difference will have to be absorbed in the Trading or Profit and Loss Account. On the other hand, rates fixed for short periods which will exactly absorb oncost expenses are likely to result in widely fluctuating oncosts which are not true, normal oncosts.

IDLENESS ONCOST

During idle hours overhead expenses are mounting up. Except for a few items, the oncost is the same whether a machine is working or not. Although part of the plant is

standing, the factory may be working with high technical efficiency. In this case, is the works to carry the burden of idle time and say that the cost of production has gone up? It is suggested that individual products should only be charged with the share of the overheads they actually use. The cost system must record the full expenses incurred during the period, but the idle overhead must be brought out separately and debited to the Profit and Loss Account.

Overheads are not a fixed charge per unit, but vary with the volume of production. They may be divided into two constituents, one fixed and the other variable in relation to volume.

In the fixed portion of overheads, profit or loss will arise according to whether the actual volume of production exceeds the budgeted output or falls below it.

As overheads are forecasted for each trading period, if the volume of production is larger than anticipated they will be over-recovered in a period of prosperity, and the point arises whether this over-recovery should be considered a part of profits. It is suggested that it should rather be carried to a reserve to meet under-recovery in times of low production. This assumes, of course, that prices are stable.

DEPARTMENTALIZATION

For the proper distribution of overhead expenses departmentalization is necessary according to the manufacturing operations. The amount of indirect cost incurred by the various departments varies to a large extent. Charges for inter-departmental services may present considerable difficulty if left till the end of the year, and they should be entered promptly. The actual cost of running each department will be accurately obtained and will have a good psychological effect. The control statement may start with the allocation of indirect materials and indirect labour to the departments, including production and service (see Fig. 40).

	INDIRECT MATERIAL						INDIRECT LABOUR		Total Departmental Cost
	S.D. Material	Coal and Coke	Electricity	Gas	Stationery	Miscellaneous	Supervision	Labour	
Production Depts. A B C D									
Total P.D.									
Service Depts. A B C D									
Total S.D.									
Total P.D. and S.D.									
General Charges									
Standing Charges									
Factory Oncost									

FIG. 40. DISTRIBUTION OF INDIRECT PRIME COSTS TO DEPARTMENTS

ALLOCATED COSTS OF SERVICE DEPARTMENTS AND GENERAL OVERHEADS											
	Cost of Depart- ment's Indirect Material and Labour	Draw- ing Office	Inspec- tion	Stores	Tool Room	Time Office	Pack- ing and Trans- port	Elec- tricians and Mill- wrights	General Charges	Standing Charges	Total
Production Dept											
“											
“											
A											
B											
C											
D											
Total											

FIG. 41. DISTRIBUTION OF OVERHEADS TO PRODUCTION DEPARTMENTS

. The cost of the service departments may then be distributed to the production departments as suggested in Fig. 41.

The value of this detailed analysis showing the absorption of overheads by each productive department as a means of control will be apparent.

Overheads can only be controlled by budgeting in advance in detail by departments and fixing definite allowances for the officials in charge. The efficiency of each shop can naturally only be judged from the course of the proportion of costs under its own control.

STANDARD COSTS

Considering the historical development of costing methods, we have seen that the old system of financial accounts showed the profit or loss as a whole but did not indicate where it arose. Cost accounting showed which individual lines were responsible and therefore enabled the management to decide which to develop or which to discontinue, in which lines price-cutting would be practicable if necessary to obtain extra business, and where such a policy would be suicidal. Traditional costing methods, however, gave no measure of factory efficiency, and accounts were usually presented too late for the management to do anything about the facts portrayed.

The system of standard costs has been developed to meet these deficiencies. They may be defined as predetermined or budgeted estimates of cost based on normal output. In other words, before work is commenced the accountant establishes what it should cost, and the efforts of the management are subsequently directed to maintaining the actual cost at this level or, more accurately, seeing that it does not exceed the standard and, if possible, is less. This permits the detection of departures and variations as they arise, whether, for example, they represent losses through uneconomic use of material, labour or services or accidental increases due to unanticipated causes. These variations

are either within the control of the management or they are not, that is, they can be prevented or they cannot, but, in any case, it is necessary to know where and how they arise.

Examples of controllable variations include defective workmanship and waste of all kinds; on the other hand, idle production time, price fluctuations in materials and variations in labour rates may be considered beyond the control of the works management. Standard costs involve the principle of management by exceptions and provide a measure of factory efficiency which facilitates control of the various departments and functions. Instead of presenting a whole mass of data which the management does not want to bother with, the method of standard costs sets forth only the vital figures, indicating where the planned costs have been departed from, and discloses information in a way which invites action.

It is obvious that the use of standard costs is best adapted to continuous or repetition production and more difficult of application to general engineering work. Nevertheless, the principle should be carried as far as practical conditions permit, and the use of budgeted costs has been successfully exploited in such non-continuous work as locomotive repairs.

We dealt with the general principles of budgetary control in Book I (Chapter VI) and saw how a budget of a whole business is prepared, including a sales budget, production budget, and financial budget. Production is regulated by anticipated demand and finance adjusted to the cost of production. Production is carried out in relation to definite standards of performance set up for each functional activity, and such standards permit it to be established whether a loss or profit is to be attributed to purchasing, manufacturing, or other cause.

With regard to manufacturing, standards must be compiled with regard to the cost of labour and materials and also expenses. Labour-cost standards involve consideration

of both times and rates. Under piece rates the efficiency of labour varies according to the ratio of standard hours to actual hours. Under time rates variations in labour cost may be due to either changes in rates or changes in factory efficiency. Variations in materials cost depend on changes in either price or quantity used for a given job.

As noted above, expenses are either fixed or variable, fixed expenses including rent, rates, depreciation, etc., whilst indirect labour and materials, repairs, etc., constitute fluctuating expenses. A standard may be established in relation to the number of hours required for normal output. This classification of expenses segregates the cost of idleness and the cost of production, the former being carried to the Profit and Loss Account, as stated above, as it is not a factor in the efficiency of the manufacturing side.

Accounting by standard costs should appeal to production executives because, in preparing a statement of what a product should cost, due weight must be given to each contributory factor and attention is called to abnormal manufacturing operations. In the past, cost accountants have been apt to overlook the importance of actual production, whereas under standard costs they cannot do so. The accounts are drawn up to follow lines of managerial organization, and reports following rapidly on the events permit the location of, and fixation of responsibility for, excesses. They also disclose tendencies in costs and enable the management suitably to modify its policy.

Standard costs keep bringing back the attention of the management to profit-making in that they disclose all factors tending to reduce the budgeted profit.

No engineer is, however, likely to overlook the necessity for the periodic review of standards in the light of technical developments and improved methods.

COSTING STATISTICS

The culminating point of a costing system is the statistical reports made by it. We have referred in a general way

to the importance of statistics and graphs as an instrument of control in Book I, and costs are only a special but very important case. The fundamental point to remember is that the costing system is the servant of the management and, whatever may be the key factors in the costs of a given firm or enterprise, they must be presented in a suitable form so that their significance can be immediately grasped.

The cost features which may be required are too numerous to detail but some of the more obvious ones are—

- Cost of factory orders or fluctuations in costs of production.

- Statement of direct costs.

- Statement of indirect expenses, the rate charged and the true rate.

- Deviation between estimated and actual costs.

- Profit or loss on actual orders.

- Ratio of factory cost to value of orders.

- Statement of idle time or percentage of capacity being worked.

The management wishes to ensure that production is being achieved by the quickest and most economical means consistent with the maintenance of quality and fair remuneration to labour, and, therefore, it not only wants to know what the costs have been but what they should have been and the reasons for any divergencies or discrepancies. To ensure that only the minimum amount of capital necessary to the enterprise is locked up, statements must be returned of the value of raw stock and work in progress, also the amount spent on new tools and fixtures.

The cost summaries submitted to the management must show which lines are paying, which shops are paying, and so on. The information submitted must be important, that is to say, the management does not want "loading" with a bulk of detail, but only to have available the vital figures in its work of control. The simpler the returns the

•better are they able to expose any inefficiencies or abnormalities which may arise. It goes without saying that cost statements must be accurate or their whole purpose is vitiated and the management misled. •

We have noted that, in the past, cost figures usually were presented too late for the management to take prompt action. In these days of severe competition and rapidly changing conditions, the period of presentation of reports needs to be minimized. In some industries weekly and even daily figures are practicable and prove of the utmost value in the determination of managerial decisions.

It is of the utmost importance to bring to the notice of all executives the costs with which they are concerned, i.e. which their actions or decisions control. Suitable statements should be submitted right down the line of control to the foremen so that they realize how much of the expenses with which they are concerned is going in different directions.

Reference may be made to the practice of some firms of submitting weekly cost data to the foremen, followed by a meeting with the works manager and accountant at which the figures are discussed and explanations called for. The moral effect is marked.

LINKING UP COST AND FINANCIAL SYSTEMS

In cost accounting there is, as we have seen, a certain amount of estimating, particularly with regard to oncosts. The Trading Account deals with actual expenditure, yet there should be agreement between the financial and the cost accounting figures. For obvious reasons, this is usually not the case, cost accounts frequently giving more favourable results. Some slight adjustment is therefore necessary at the end of each period in order to reconcile the two sets of figures.

We have noticed above some of the advantages of classification of accounts. This procedure should be adopted as regards the control accounts in the Cost Ledger, and, if the financial accounts are subdivided and arranged in

parallel with the costing system, the work of reconciliation is facilitated. It should be noted that agreement between the two sets of books at any moment does not necessarily prove that the cost accounts are accurate, because the oncosts were established on the last period, whereas the expenses for the current period are not yet fully known.

DIFFERENTIAL COSTS

It should be observed that the lowest price at which orders can be accepted is not, as is sometimes supposed, the prime cost, but the difference between the cost of producing and the cost of not producing, or the cost of *added* production. This is called the differential cost, and is frequently a matter of considerable complexity, as it may include a number of fluctuating oncosts varying with output. Management may, however, require to know, above all else, what is the lowest price at which a given output can be sold without loss.

Suppose it took £50,000 to manufacture 10,000 sewing machines and £60,000 to make 12,500, then the cost per machine is £5 in the first case and £4 16s. in the second case, but the differential cost of producing the extra 2500 machines is £4 each. These might be sold abroad on a basis of £4 without affecting the home market on a basis of £5 cost each. This is, in fact, the principle of dumping, with regard to which some very loose statements are occasionally encountered.

When it is said that the exporters of dumped goods are selling below cost, the expression is practically valueless as no reference is made to the load-factor of the factories concerned. The managements of such factories endeavour to run the plants at the point of least cost per unit, and therefore the cost of producing the last "increment" is extremely low. Even if they are selling below cost, their loss may be less than if they did not make the dumped goods.

The principle of differential costs will also be familiar

in regard to the charges for travelling by excursion train, for consuming electric power at night, and the rates for evening telephone and telegraph service as well as for deferred cables.

Reverting to factory work, the management will need to know the costs for different load factors and, as in estimating oncosts, a particular loading will have been formulated, the management will be able to decide whether it will pay better to take or not to take a particular order or line of work at the price obtainable. Moreover, costs will generally be lowest with uniform loading, although the sales may be fluctuating or seasonal.

DEPRECIATION

The current value of a plant is obviously not the amount originally expended on it. It will have diminished in value due to the lapse of time, the influence of the elements, wear and tear in use, and perhaps it has not been maintained in effective repair. New designs and inventions may have rendered available machines which will perform the work more efficiently. Changes of taste or fashion or a rise in the cost of materials may have destroyed demand for the machine's products.

This diminution in value of a plant or machine with time may therefore be divided into two factors, depreciation and obsolescence. The latter is due to the machine growing out of date or becoming old-fashioned. Depreciation is the unavoidable deterioration in value due to wear and tear in use even if the machine is kept in proper repair. Maintenance or keeping in repair is in fact an additional expense which has to be provided for in the cost of running the machine.

Plant and machinery are bought for the purpose of earning an income and diminish in value during their life until they have to be replaced. Provision for replacement of these assets must therefore be made, and this can only be made from an equitable accounting point of view from the

income derived from their use. There can, in fact, be no true profits without providing for all expenses involved in carrying on production on a permanent basis.

The original cost of each fixed asset, together with all expenditure thereon but minus its residual or scrap value, is therefore a charge against revenue and this charge must be spread over the asset's life as fairly as possible. Its life is, of course, the period over which it is economic to retain it in service; this may be much less than the period over which it would continue to be usable.

To provide the purchase price for replacement of an asset a sum of money must be deducted annually from revenue and set aside to give the desired amount at the end of the working life of the asset. It is imperative to create a depreciation reserve or sinking fund, and to earmark it for the purpose. To use the depreciation fund for working capital is dangerous, particularly in small businesses. New capital to replace assets should never be necessary except as the result of accidental destruction or in the event of progress in invention suddenly rendering the assets valueless.

METHODS OF PROVIDING FOR DEPRECIATION

There are several methods of providing for depreciation, the object being to determine the proper sum to charge against revenue to cover the deterioration of the machine or other asset. The choice of method depends on the actual circumstances.

1. *The fixed instalment method* involves writing off each year an equal proportion of the cost of the asset to reduce it to its residual value at the end of its life.

Let I be the initial cost, R the remanent value and N the years of life.

Then the sum to be set aside each year is $\frac{I - R}{N}$. This simple method makes no allowance for the fact that repairs and renewals are largest towards the end of an

asset's life, and the total annual cost of upkeep will therefore be larger.

2. *The diminishing balance method* consists in deducting depreciation at a fixed rate per cent on the balance outstanding at the beginning of the year. With the above symbols, and denoting by p the constant percentage required to write off the asset in N years, we have—

At the end of the first year the depreciation fund is

$$Ip$$

At the end of the second year the depreciation fund is

$$Ip + (I - Ip)p$$

At the end of the N th year the depreciation fund is

$$I\{1 - (1 - p)^N\}$$

which equals

$$I - R$$

or

$$p = 1 - \sqrt[N]{\frac{R}{I}}$$

This does not allow for the interest accruing on contributions.

If we allow r to be the rate per cent payable on the yearly sums invested, the formula is as follows—

At the end of the first year the depreciation fund is

$$Ip$$

At the end of the second year the depreciation fund is

$$\begin{aligned} & Ip(1 + r) + p(I - Ip) \\ &= \frac{Ip}{p + r} \{(1 + r)^2 - (1 - p)^2\} \end{aligned}$$

At the end of the N th year the depreciation fund is

$$\frac{Ip}{p + r} \{(1 + r)^N - (1 - p)^N\}$$

which equals

$$I - R$$

and from which the constant percentage p can be obtained.

3. *The interest law method* provides for depreciation by crediting the asset account with equal yearly amounts and debiting it with the interest that would otherwise be earned by the capital invested in the asset. The interest is eventually carried to the credit of the Profit and Loss Account. The annual increments, minus the interest on the yearly balances of the asset account, indicate the necessary amounts to be set aside for replacing the asset at the end of its forecasted life.

Let S be the sum set aside each year.

Then at the end of the first year the reserve is

$$S$$

Then at the end of the second year the reserve is

$$S(1+r) + S = \frac{S}{r} \{(1+r)^2 - 1\}$$

Then at the end of the N th year the reserve is

$$\frac{S}{r} \{(1+r)^N - 1\}$$

which equals

$$I - R$$

Therefore,

$$S = \frac{r(I - R)}{(1+r)^N - 1}$$

This method is generally used in connection with leases and similar assets, since, when employed for machinery, fresh calculations are necessary each time additions are made to the plant.

Diagrammatically, the accumulation of the reserve for replacement may be represented for the three methods mentioned above as shown in Fig. 42.

In addition to the above three systems which are in general use in the engineering industry, there are four other methods of providing for depreciation—

4. *The depreciation fund method.* This system also takes into account the fact that it is always desirable to provide the capital necessary to replace a machine that is worn out, in addition to writing off its value. The machine or

other asset is kept at its cost value, while a fixed annual sum, called the sinking fund instalment, is debited to the Profit and Loss Account. At the same time, a corresponding amount of cash is invested annually in gilt-edged securities and left to accumulate at compound interest, so that at

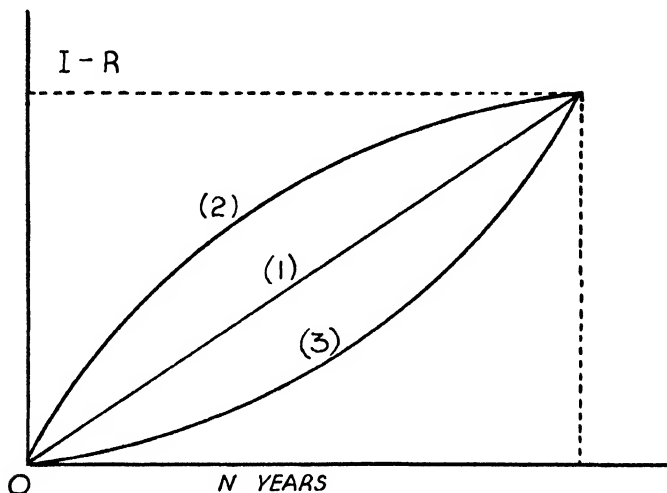


FIG. 42. ACCUMULATION OF RESERVE FOR REPLACEMENT OF AN ASSET

the end of the life of the asset the total investment will correspond to the amount required for replacement.

5. *The insurance policy method.* This is similar to the depreciation fund method described above. Instead of the annual amounts of cash being invested in gilt-edged securities, however, they are paid away as premiums on an insurance policy which secures a sum sufficient to replace the asset at the end of its life.

6. *The revaluation method.* In this method the assets are revalued each year and the revenue charged with the difference between the book value and the assessed value, the book value being duly written down. This direct method requires the services of an expert valuer. It is

generally used for loose tools and other assets which cannot be conveniently treated under the above systems.

Occasionally, expert revaluation has to be made for such purposes as evidence of value of property in appeals against rating, and with regard to income-tax allowances or claims for insurance.

7. The single-charge method. In this system a single amount to cover repairs, renewals and depreciation is charged against revenue.

Apart from the difficulty of differentiating between repairs and renewals in some cases, the necessity arises for valuing the assets fairly frequently, and also it may be found desirable to alter the amount of the annual charge.

Some undertakings, such as railway companies, take no cognizance of depreciation but pay for renewals as they arise out of funds created by transfers from revenue.

RECORDS

A Machinery and Plant Register should be kept, preferably on the card-index system, having one card for each machine or piece of plant. The purchase price, the esti-

MACHINE RECORD CARD

Machine No.	Department
Description	Bay
Original Cost	When Purchased
Cost of Installation	
Floor Space Occupied	Chart showing estimated life and depreciated value
K W. Consumption	
Depreciation Rate	

See Reverse side for Maintenance and Repairs

FIG. 43. MACHINE RECORD CARD

mated life, the method of apportioning depreciation and the remanent value are recorded on the card, or a simple graph may indicate this information as suggested in Fig. 43, though the actual graph is not shown. The reverse of the card is used for particulars of maintenance and repairs, including cost so that the total expense of upkeep is available from one card.

As regards the recording of depreciation in the books, it is advisable to open up ledger accounts for each asset as far as practicable; for example, separate accounts should be opened for different classes of machinery—engines, boilers, motors, shafting, general machinery and special machinery—as each class usually depreciates at a different rate. These accounts interlock with the financial accounts of the firm.

RATES OF DEPRECIATION

Methods of depreciation are fixed by accountants, but rates of depreciation must be determined by practical men.

In fixing the appropriate rates of depreciation it is desirable to classify the assets, e.g. buildings, machinery, etc. Tables have been drawn up showing the life in years to be expected of different types of buildings and different classes of machinery and power plant. They are known as amortization tables, and the student should consult engineers' handbooks or other sources for the depreciation usually allowed.

Freehold land and buildings must be separated in the accounts. The cost of any additions or partial rebuilding is debited to the asset account affected, as it is not properly chargeable against the profits of the year in which it is incurred, but is spread over a period. Freehold land and buildings are usually depreciated at $2\frac{1}{2}$ to 5 per cent annually. In fixing the depreciation of leaseholds, it must be remembered that all expenditure on and during the lease is really payment in advance for rent, and that nothing must remain in the accounts as capital outlay in connection with the lease after its expiration. If the lease

has been purchased by payment in advance, revenue may be credited with interest on the investment.

The depreciation of engines and boilers depends on the pressure at which they are worked, whether stationary or not, and so on. The rates may vary from 10 to 20 per cent on the reducing balance; for fixture and fittings, shafting, etc., the allowance is considerably lower, viz. 5 to 7½ per cent.

Loose tools are subject not only to the risks of depreciation but of loss and theft, and it is best to depreciate them by revaluation at frequent intervals.

Moulds and patterns should be written off rapidly, and are frequently treated as revenue expenditure, especially if no further orders are expected.

It should be noted that an income-tax rebate may be obtained under the heading of wear and tear, which does not, however, necessarily coincide with the estimates of depreciation as ordinarily defined or considered.

With regard to patents it is claimed that they should be treated as if they were leases of 16 years' duration, but a valuable patent always has a residual value expressed in goodwill. It is usual to accumulate a reserve rather than write off the book value of a patent.

The charge for depreciation of a machine has to be recovered from the work performed on or by the machine. Thus, if the number of hours running is estimated, a depreciation charge can be included in the machine-hour rate of oncost recovery.

A point which sometimes arises is whether it is advantageous to invest in relatively inexpensive light machinery or more costly durable machinery. If depreciation is reckoned on the straight line or diminishing-balance method, the latter type of plant appears preferable in many cases, but, if allowance is made for interest on the sum invested, the less durable type may appear the more economic proposition, and particularly if the risk of obsolescence is real.

OBSOLESCENCE

A distinction must be drawn between the need for replacement of equipment by wear and tear and the same need when caused by rapid technological development. In modern times the latter consideration is probably the more important. A machine does not need to wear out before it must be replaced. Its useful life is over when it ceases to work profitably. New inventions may render it relatively inefficient although it is in good working condition and its productive value little affected.

Henry Ford says that it is considered wasteful for a manufacturer to retain a machine if another appears that will do the work better or more cheaply. The general theory of replacement is not, however, quite so simple as this. Bearing on the decision is a complex set of circumstances, including the remanent value of the old machine, the first cost and depreciation rate of the new machine, how much more efficient it is, whether it can be kept employed all its time, and so on.

The rate of obsolescence is the same whether a machine is working or standing, but, on the other hand, obsolescence usually occurs by jumps. It may occur for any of the following reasons: a new machine may do the work at lower cost, the product may be replaced by one for which the machine is unsuitable or improved in a way for which the machine is not adaptable, and changes may occur in taste or fashion as regards design.

For general machinery the risk of obsolescence is much less than for special machinery. General machinery usually finds a market, but special machines usually have only scrap value. The latter machines must be depreciated rapidly, especially if the principle of the machines has been determined by the nature of the article manufactured. The actual position must be frequently reviewed and compared with previous estimates.

Any estimate of the economic life of a plant must therefore necessarily contain an arbitrary factor, as the extent to

which practice will improve in the next few years can only be guessed at.

With the present acceleration of progress and invention it is, however, safe to presume that a plant is more likely to become obsolete than wear out. British machinery, for example, may suffer from longevity. It has been stated that machine tools are obsolete in ten years on an average, worn out in thirty years, and written down to scrap value in fifty. It all depends, of course, on the amount of use, but it seems uneconomic to run expensive machinery 47 hours a week out of the 168 possible. If it is impossible to design machine tools to wear out in ten years on the lines, so to speak, of "the one-hoss shay," a suggested remedy is to run them three times as long per week. Of course, maintenance would be three times as much, but capital would be turned over more quickly and the shops kept up to date.

In any case, obsolete shops are injurious to the whole industry. Manufacturers are, of course, aware that it would be better to have a more drastic writing-off, but the allowance on income tax for wear and tear is only 5 to $7\frac{1}{2}$ per cent on the previous year's value, so that industry is frequently not able to keep its capital intact although the law says it is.

If the allowance were increased to 10 per cent, there would be less temptation to keep plant after ten years' life. This question has undoubtedly been a factor in the early replacement of machinery in the U.S.A.

Obsolescence applies to much more than machinery. A whole factory, for example, may become obsolete if it is not possible to modify its lay-out or internal transport to meet modern conditions, or external transport developments may render the position of the factory obsolete.

The two most important factors in industry are, however, machines and brains. For the latter to be obsolete is worst of all.

MAINTENANCE

A plant is a wasting asset, and maintenance is the keeping of the plant in productive condition. It includes such work as cleaning, rectifying defects and effects of misuse, lubrication and prevention of wear, the repair of parts and the provision of spares.

The aim of maintenance is to ensure freedom from breakdown and interruption in production. By diminishing the effects of wear and tear, it extends the life of a plant (in the absence of obsolescence) and renders its operation more efficient.

Maintenance constitutes a charge distinct and separate from depreciation. The expense is estimated in advance and met from a Maintenance and Repairs Equalization Fund, to which equal sums are credited annually, the amount of which is determined by experience. It must be remembered that the maintenance department is an overhead, so that wages and salaries must be included in the expense. The work of the maintenance department will be considered in Chapter IX.

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CHAPTER VIII

SITE AND LAY-OUT OF WORKS

FACTORY LOCATION

IN this country the manufacturer about to establish a manufacturing business has usually a choice of locations. His aim is, of course, to find the optimum from the point of view of long-run profits, having regard to the business as a whole, i.e. including the purchase of raw materials, the actual manufacturing process and the sale of finished products. The elements involved are technical, commercial, and financial, and the object sought is the location yielding maximum returns.

The following are the principal economic aspects of plant location.

1. *Availability of raw materials.* Proximity to sources of raw materials is the obvious explanation of the location of some of our old industries, e.g. the early localization of the iron industry in Sussex and its subsequent migration to the north of England. Other illustrations will occur to the student, such as pottery in the Black Country, chairmaking in Buckinghamshire, and so on. In modern times, however, immediate access to raw materials has become of diminishing importance.

2. *Proximity to markets.* The advantage of being near the centre of demand for the finished products, or alternatively at a good distributing centre, needs no emphasis. Not only is the firm and its products likely to be better known but the cost of distribution is an important item in overhead expense, and as between two firms having equal manufacturing costs, it may be sufficient to give the nearer firm a competitive advantage. The recent growth of light engineering and semi-luxury trades near London is largely due to advantages to be derived from such a concentrated

market and such a good distributing centre by sea, road, rail, and air.

3. *Transport facilities.* We have seen from the above that freight paid on raw materials and finished materials enters into the costs of production, and in recent times transport facilities may well be the governing factor in economic location. For firms handling heavy products water transport is usually essential. In this connection we may note the location of the Ford factory on the Thames, not only in connection with incoming coal and iron but on account of proximity to London and Continental markets. For firms with an important proportion of foreign trade, proximity to docks is a valuable factor. Within the country the chief modes of transport are rail and road. In recent years railway companies have shown themselves more accommodating in regard to the provision of private sidings for industrial firms. The low cost of motor-truck haulage has, however, made it a strong competitor in industrial transport. It has, of course, the advantage of door-to-door delivery. Its effect may be seen in the location of an increasing number of factories alongside arterial roads.

4. *Availability of power.* Last century the localization of industry was largely influenced by the necessity for proximity to the coal fields as transport costs were high, but the development of electrical power for industrial use and the construction of the high-tension grid system of distribution have had a centrifugal action and assisted the distribution of industrial plants away from the fuel sources. Unfortunately this country is not well supplied with hydraulic power, but the localization of aluminium and other plants on our few resources is accounted for by the cheapness of this method of generating electrical power.

The gas grid constructed in South Yorkshire may be followed by others and this distribution of coke-oven gas will further assist the tendency towards decentralization of crowded industrial areas.

5. *Climatic and atmospheric conditions.* Climate as between parts of the British Isles is not an important factor. The classical example is the localization of the cotton industry in Lancashire, but with the great strides in air-conditioning it is possible, if not economically practicable, to maintain the atmospheric moisture content in any factory at a stipulated figure. Of course the further north, the greater the cost of adequately heating a factory throughout the year and most factories fight shy of a locality where the atmosphere is contaminated with fumes which may be deleterious to the product or greatly increase the costs of upkeep and maintenance owing to corrosive attack.

6. *Availability of labour.* In choosing a location regard must be given to the possible or potential supply of suitable labour, not only as regards amount, but the right kind and obtainable at the right price. Some industries require highly skilled labour, others unskilled but intelligent. Obviously the former type might be difficult if not impossible to obtain in rural areas. Cheap labour is not necessarily low-paid labour, but there are some industries which cannot pay high wages and must consider locating in a district where female as well as male members contribute to the family income.

7. *Momentum of an established industry.* If an industry has obtained an early start in a district, there grows up in it a body of skilled and expert workmen with an instinct for the class of work possibly developed over generations. The district acquires a reputation for high quality which has a real publicity value. Specialization of the district helps to localize institutions engaged in research and centralizes progressive work there. Even if some of the original advantages of the location have passed, momentum may carry it along, and community of interest prove more attractive to a manufacturer than erection of a works in another part of the country. Incidentally, there may be satellite industries there developed to take the waste or by-products of the works.

8. *The preference of outstanding business men.* There seems to be no explanation but a personal one to account for some locations, such as the manufacture of cars at Oxford, windows at Braintree, and so on.

9. *Good water supplies.* Apart from the abundance of water required for cooling purposes in power houses, purity of water may be essential for some industrial processes, softness of water for others. An example is the use made of the Liffey water at Dublin or the Don water at Sheffield.

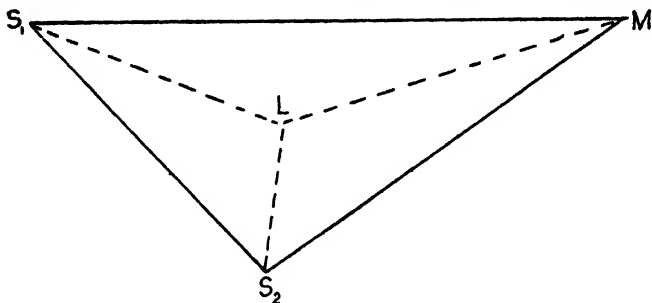


FIG. 44. DIAGRAM ILLUSTRATING THE DETERMINATION OF THE MOST PROFITABLE LOCATION FOR A FACTORY

To illustrate the factors involved in finding the location of greatest profit, in Fig. 44 let us assume the following simple case of two sources of supply S_1 and S_2 of raw material and one point of consumption or marketing centre M . Let L be the location of the manufacturing plant. Then it is obvious that if L is at M only freight on raw material will be paid, or if L is at S_1 or S_2 there will only be delivery charges on the finished product; if at an intermediate point, both incoming freight and outgoing delivery charges will have to be paid. In practice a comparison would be made of each constituent of the total cost which would be involved if the plant were erected at each of the alternative sites, as shown by way of example in Fig. 45. The location which involved the minimum total cost per unit would, in the absence of any overriding policy considerations, be chosen as the site for the plant.

In the early days of the Industrial Revolution, the localization of industry was mainly determined by proximity to cheap power and accessibility to raw materials due to difficulty of transport. Specialized regions arose having a central basic industry, which whilst possessing advantages, some of which have been referred to above, also suffered

Item	Charge per Unit at Site			
	S	S ₂	M	L
Raw Materials $\left. \begin{matrix} (a) \\ (b) \\ (c) \end{matrix} \right\} d/d$				
Fuel and Power $\begin{matrix} \text{Coal} \\ \text{Electricity} \\ \text{Gas} \end{matrix}$				
Works Expense $\begin{matrix} \text{Labour} \\ \text{Superintendence} \end{matrix}$				
General Expense $\begin{matrix} \text{Administration} \\ \text{Taxes} \\ \text{Insurance} \end{matrix}$				
Distribution $\begin{matrix} \text{Packing} \\ \text{Transportation} \\ \text{Sales} \end{matrix}$				
Total Cost per Unit				

FIG. 45. TABLE TO DETERMINE THE LOWEST COST SITE

greater fluctuations than districts in which the work was diversified.

As time goes on, new processes render existing trades and occupations obsolete, and revolutions in transport make whole districts obsolescent. In the last half-century the electrical industry has arisen and favoured the growth of light engineering at the expense of the earlier heavy mechanical engineering work. These developments have tended to alter the distribution of industry in the country.

In Book I (Chapter II) we noted the shift of industry

northward, to the coalfields following the application of generated power to factories, and it is evident that the present age is characterized by a shift in the centre of gravity of industry back southwards again. South-east England is now the most important industrial area in the British Isles. Some of the reasons for this southward trend of industry are apparent from the above considerations.

The magnitude and density of the population in and around London constitute the largest concentrated market in the world as well as an enormous labour reservoir. Improved transport facilities, both rail and road, in and around the metropolis, have opened up many new industrial districts and also permit workers to live remotely from their places of employment. London is a first-rate seaport and airport and one quarter of the whole country's aeronautical industry is centred round it. Its financial and commercial facilities are unrivalled. The development of the grid system has brought cheap power to London and its surroundings and made them attractive to manufacturers of an extremely wide range of products. How long will the movement of industry southwards and towards London last, and where will it end? This question provides food for thought not only by the economist but by the sociologist as well.

URBAN *v.* RURAL SITES

The relative merits of town and country locations will have to be considered. In a town there is practically sure to be good rail and road connections for collecting and distributing. A good labour supply will be better assured. Power and water will be readily obtained from the local authorities. The town site will have a good advertising value, for not only will more persons pass it, but the urban council will probably carry on an advertising campaign of the town and its industries. There will be technical and commercial schools for training operatives and staff. Financial and commercial facilities will arise in the aggregation of business men.

On the other hand, land values in urban areas will be high if purchase is contemplated or alternatively the price of leases and rents will be higher than in the country. Rates will also be heavy and the wage level higher than in rural areas. There will be less possibility of expansion due to the probability of the urban area being built up.

Amongst the advantages of country sites are cheap land and low rates, lower wages due to lower cost of living, lower insurance charges due to less fire hazard. In the case of industries which can only be housed in one-storey buildings, the economic advantage of the low land values will be considerable and an ample margin can be allowed for expansion. In the country there are also as a rule less restrictions in building.

The supply of labour may, however, present difficulties. There are less social amenities in the country, and even if a large firm finances a housing scheme for its labour the attractions of town life are very strong to operatives who have once dwelt in cities. Moreover, as there are less likely to be subsidiary industries, working-class families may have to break up so that all members can find work. Housing certainly constitutes a problem in the country; even if a firm arranges transport facilities there is little doubt that operatives prefer to live near their work. Nevertheless the distribution of factories into rural areas would have definite social benefits as the ill-effects of overcrowding on the working population in towns are too well known to require discussion here. As stated, the increasing speed of transport allows people to live farther from their work, and town planning with satellite residential areas will prevent, in future, factories being jumbled up with residential quarters. There is a tendency for trading estates to be constructed on which industrial premises are segregated and laid out with full amenities for power, transport and communications. These trading estates may be an index of the industrial planning of the future.

The mention of the rise of trading estates on which

buildings may be erected to attract industrial occupants. raises the question of buying versus leasing a factory, which has received considerable attention in the United States. The cost of operating a factory at a planned industrial centre may be less than on an isolated site. Whilst a firm is usually established to last indefinitely, the progress of technical knowledge and invention is so rapid that it is impossible to say exactly what some firms will be making a few years ahead. For firms which cannot foresee a continued demand for their products, investment in a lease may prove more economic than in the ownership of a factory. In this country, however, it is generally considered that if a company has sufficient money to buy its own factory and still leave a surplus to avoid the need of temporary loans, the advantage lies in ownership.

Ownership is evidently advisable if the leases available are short and the cost of moving equipment is high, or if a highly specialized factory is required there is probably no alternative.

The reason that a firm moves to a new site is usually that its work is expanding so fast that it cannot be housed in its existing premises. A warning should, however, be raised against moving to a large and expensive site. The management should make quite sure that reorganization and rearrangement and improvement in materials handling equipment will not ensure the increased capacity desired before deciding to erect a larger and expensive factory elsewhere. Production cannot be accurately predicted very far ahead and there may be danger in the optimism of temporary success.

SELECTION OF SITE

In passing from the general locality to the actual site further considerations arise. First of all allowance must be made for expansion or in a few years the plot of land may be rendered unsuitable. A careful survey of the projected site is necessary as any latent disadvantage entails an

expenditure for all time. Is there any sunken stream crossing the site or any sewer or pipes or tunnels carrying cables? Is the subsoil suitable for foundations and drainage? Is it possible readily to dispose of trade wastes? It must be remembered that a level site is not necessarily the best for a satisfactory lay-out. It may have to be excavated for processes to be carried on at lower levels. On the other hand, on a site that is not level lay-out will be facilitated in a plant in which gravity conveyance is inherent in the process. In some cases a low-lying site is advantageous, but swampy ground increases the expense of laying foundations and building costs. Careful examination must be made of the title deeds to see there are no encumbrances on freehold property, rights of way, or way-leaves. It is expensive for any snags in possession to be discovered afterwards. Local building laws must be carefully studied and it must be ascertained if any town planning schemes or projected road widening will affect the site.

Land values must be critically examined in the light of possible appreciation and capability of industrial development. The questions of ground rent, rates and taxes, legal restrictions, and financial facilities of the district will require attention.

As regards the receipt and dispatch of goods, a river site is advantageous for coal and other mineral transport and usually solves the water problem, including fire protection, but it must be remembered that more will be spent on painting the factory, and the fog nuisance is likely to arise. If rail transport is to be relied on the factory owner should note that sidings are only taken from the slow track, goods loop, and near a signal box. With regard to lorry transport, access to two roads is desirable and whilst lorries have to be cleared immediately, wagons can be retained for three days.

In considering power supply and services which may in some factories be the ruling factor, electricity supply from the grid system is usually available and the necessity of generating does not frequently arise, though the nature of

the industry and the size of undertaking have a bearing on this. With regard to factories using gas, consideration should be given as to whether it is more economic to consume the town's gas or erect a gas generating plant. The type of labour in the district must be studied with a view to obtaining the best kind of operatives for the work. Is there sufficient housing in the district for the requisite quantity or can it be brought from a nearby centre if adequate transport is arranged?

FACTORY PLANNING

Having decided the location of a factory, fixed the immediate and potential capacity, and selected the site, it must be remembered that the plant is really a working tool—the most important of working tools, into which all others have to fit—and must be given the best possible conditions in which to function.

There is no need to emphasize the necessity for planning a plant to obtain the most economical manufacturing sequence of operations and most efficient production methods, and, therefore, lowest costs. In the past it has been known for a factory to be erected and no thought given to planning till things went wrong; it was then too late to prevent severe losses. Planning a plant to ensure continual operating efficiency is no easy matter, and one in which experience counts for a good deal; plans which seem all right on paper often fail to stand the stress of practical everyday working.

As the object of a manufacturing enterprise is to produce as much and as efficiently as possible, with a minimum total cost per unit, it is apparent that too much care and attention cannot be given to the lay-out, design, and equipment of the factory, and the handling of tools and materials consistent with the essential consideration that the investment must be warranted by the business available. It must be remembered, however, that a factory is something more than the buildings and working tools. It is a complex

organization which takes in the raw materials and delivers the finished products, and in which the human element is prominent if not pre-eminent. When, therefore, the term "maximum production" is used, it is intended to mean the greatest compatible with the well-being of the working force, and as experience has shown that human effectiveness is dependent on industrial environment, the economic importance of correct factory design and lay-out is further emphasized.

FACTORY LAY-OUT

The function of a factory is production and in modern factories manufacture must be highly organized and controlled on scientific lines. To yield real economies, factories must be designed about the processes they are intended to house; haphazard lay-out is conducive to loss and even danger.

The first point then in deciding factory lay-out is the nature of the product, and what and how much is to be manufactured, as it is obvious that the scale of operations may quite possibly modify the general lay-out.

The initial producing capacity will be fixed by what is reasonable in view of the buying power of the market and the existing supply, but the factory will be planned for rapid enlargement if necessary. The lay-out of a plant offers many complex problems for the designer, and will depend on the function for which the plant is intended, the type of industry, the product manufactured, the operations worked, and other factors. To start with, a lay-out which causes products to retrace their steps in the plant, or to be handled for long distances or an unnecessary number of times, is costly, and a burden to production from the outset. This emphasizes the necessity for a direct line lay-out, i.e. adequate internal transport for minimum movement of materials, with convenient centres for works stores and auxiliary services.

Fig. 46 shows two simple direct line lay-outs with auxiliary services arranged to feed direct into the departments or

sections requiring them and the product passing straight through the factory from receipt of raw materials to dispatch of finished goods.

A suggestion for a plan of a works making an engineering product such as a motor-car engine is shown in Fig. 47.

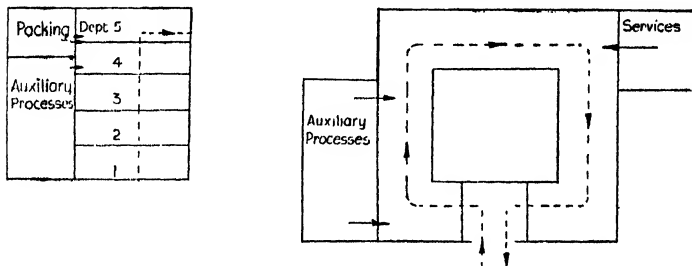


FIG. 46. SIMPLE DIRECT-LINE LAY-OUTS

It will be noted that the materials in the course of manufacture move forward continuously in a straight line. A foundry is shown, but the question to decide first is whether it will pay; in other words, can castings of the

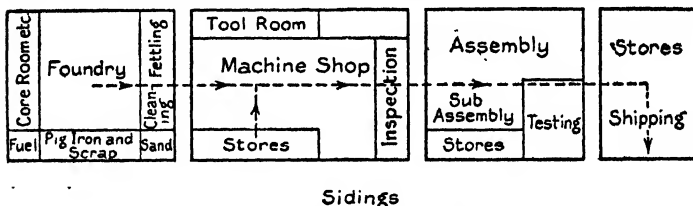


FIG. 47. STRAIGHT-LINE LAY-OUT

necessary precision be purchased more cheaply outside from a specialized firm? Similar considerations apply to the pattern shop, viz., will it pay to make the patterns required? The provision of good internal siding facilities is essential for the expeditious receipt, handling, and distribution of raw materials, and semi-finished or wholly manufactured parts, so that they can be taken direct to the shops where further operations have to be performed on them or to the most conveniently situated store, in order that further handling may be reduced to a minimum.

GROUP v. LINE MACHINE LAY-OUT

The next point to decide on is the system of manufacture to be employed. There are two main methods of lay-out, the shop method in which similar types of plant are grouped in departments and the line method of production and assembly. There is, however, frequently a combination of the two, involving manufacturing sequences whilst retaining the specialized groups associated with the shop method.

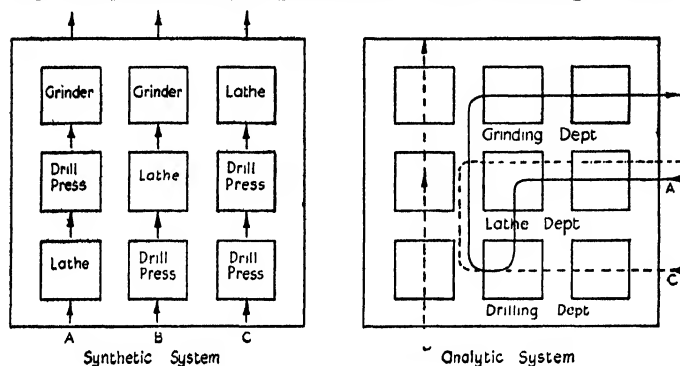


FIG. 48. MACHINE LAY-OUTS

Is the production equipment to be laid down on the flow or the group system?

The synthetic system of manufacture in which processes follow an orderly sequence is undoubtedly the most economic for production on a large scale, but the plant in many engineering firms is still arranged on the group system. The latter might be designated an analytic system as products are routed to machine groups in accordance with the operations required, but do not progress in a straightforward flow. Many nice problems arise as to when it is economic to break up a group system and lay down a special production line.

The two systems are simply illustrated in the accompanying diagram, which should be self-explanatory as concerning the manufacture of three products A, B and C in alternative lay-outs.

FLOW WORK LAY-OUT

Let us consider further the line system in which the lay-out follows the process flow diagram. The process engineer will establish the production centres to apply the

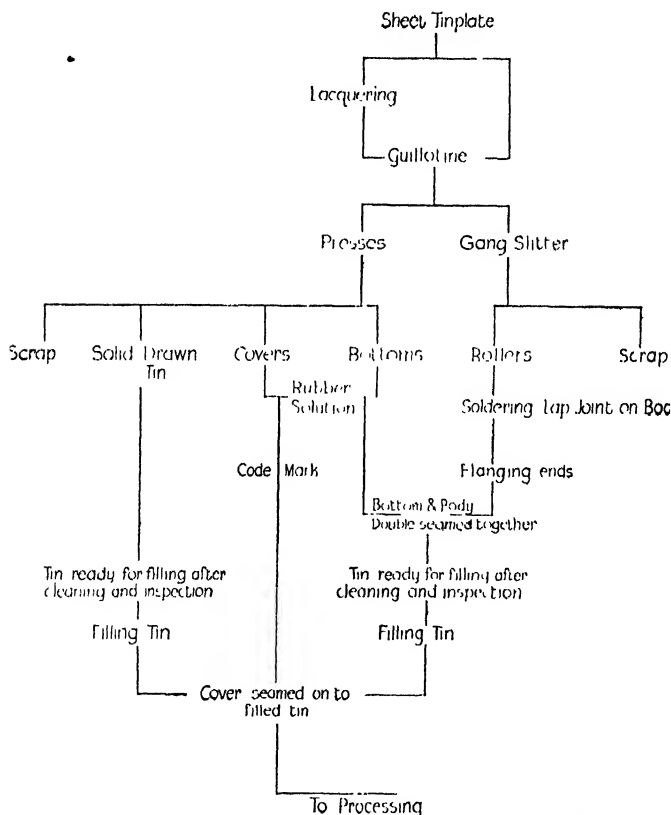


FIG. 49. FLOW SHEET FOR THE MANUFACTURE OF A CAN FOR FOOD PRODUCTS

well-known straight-line principle, making each process a move forward, branching or connecting the flow lines where necessary, balancing the capacities of each stage of production, and using space economically, but with an eye to ease

of future expansion. The conversion of a flow sheet into a plant lay-out may be illustrated by the accompanying diagrams relating to the manufacture of tin cans in a canning

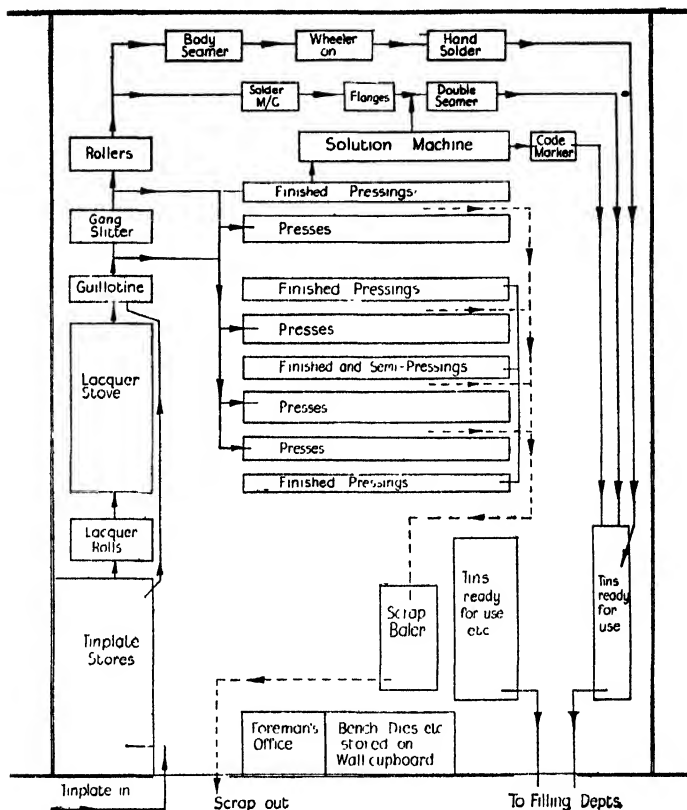


FIG. 50. SUGGESTED LAY-OUT FROM FLOW SHEET

factory. The direct flow and the short moves will be noticed. The tin-plate is brought in and the scrap removed periodically, but the tins may be passed out continuously on any suitable form of gravity runway.

Further, to illustrate the straight-line lay-out, diagrams are given referring to a chair factory, a car bodywork factory, and a metal-box factory (Figs. 51, 52, and 53).

Railway Sidings

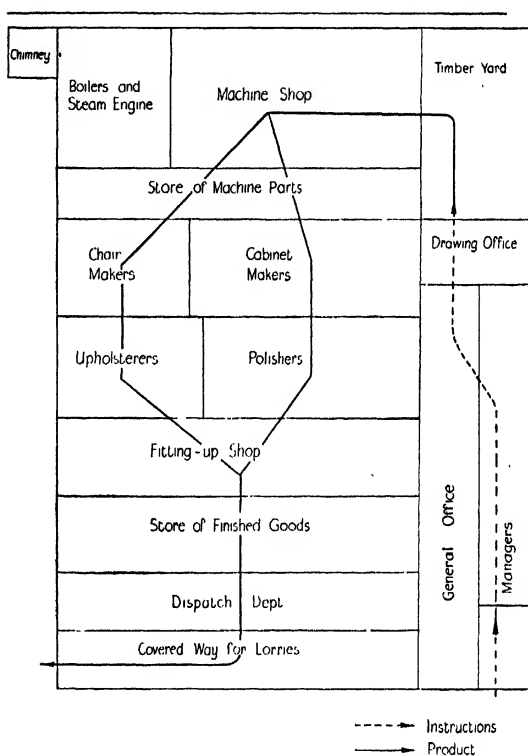


FIG. 51. LAY-OUT OF A CHAIR FACTORY

SUBSEQUENT STEPS

The next feature in lay-out is to make provision for the external and internal transport, including labour aiding and saving devices. Movement will be minimized, and adequate

transport capacity secured with a view to eliminating accumulation of raw material or finished work in a way to

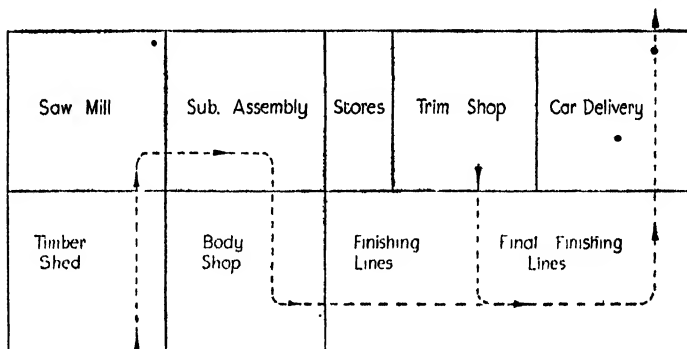


FIG. 52. CAR BODYWORK FACTORY LAY-OUT

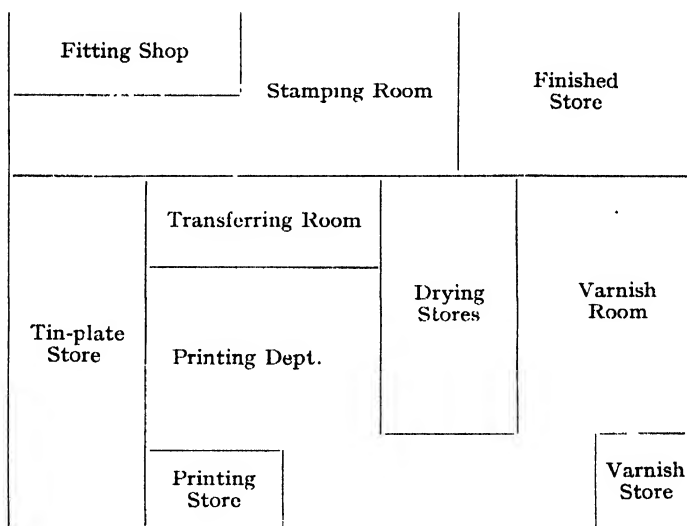


FIG. 53. LAY-OUT FOR METAL-BOX MANUFACTURE

interfere with the producers. The next point is to arrange for service centres (stores, inspection, tool-room, test-room, auxiliary services, offices) at the most strategic points and

consistent with the optimum utilization of space. The choice of the most efficient plant in relation to the projected production is a technical matter and will not be

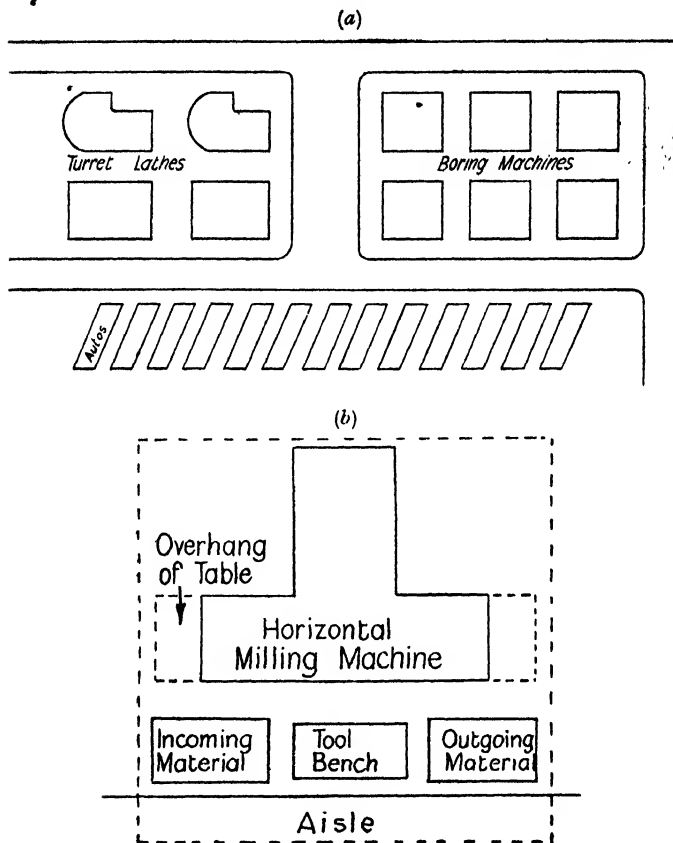


FIG 54. USE OF TEMPLATES IN LAY-OUT.
SCALE MODELS OF THE MACHINES MAY BE
MADE IN CARDBOARD

referred to here except to say that productive capacities must be balanced to prevent bottle-necks. In laying down the position of equipment and arrangement of machines

recourse may be had with advantage to the use of floor space templates as illustrated in the accompanying diagrams (Fig. 54). This permits the convenient arrangement of plant in the proper sequence, ensures that the floor is not too crowded and the gangways adequate and establishes in advance conformity with the Factory Acts and by-laws.

The fact should not be overlooked that the work may have to stand temporarily by the machine either before processing or when awaiting inspection and benches may be required for tools, so that the pieces of cardboard may usefully be made to cover the area required in servicing the machine. Particularly with large machine tools, it is the size of the production centre which is important rather than the plan area of the machine itself.

Consideration will be given to the methods and arrangements for supplying power, water, compressed air, steam, and so on as required by the processes in question. The location and arrangement of departments may now receive attention, including the choice of single or multi-storey buildings; wing or bay construction multi-storey buildings may already have been suggested by a desire to use gravity flow.

The receiving and dispatching departments are obviously best located on the ground floor. Good examples of multi-storey lay-outs may be found in the textile industry. In worsted yarn plants, for example, the raw material may be blown in on the third storey, carded and fall down chutes to the first storey where it is combed, and fall by gravity again to the ground floor where the short fibres may go one way and the long fibres the other to the drawing, twisting, spinning and winding operations.

In single-storey buildings use may be made of the unit system, the factory being divided into a number of bays, each a complete unit, which reduces costs by standardization and repetition. Fig. 55 shows the lay-out of a works on the unit system, each bay being adapted for the

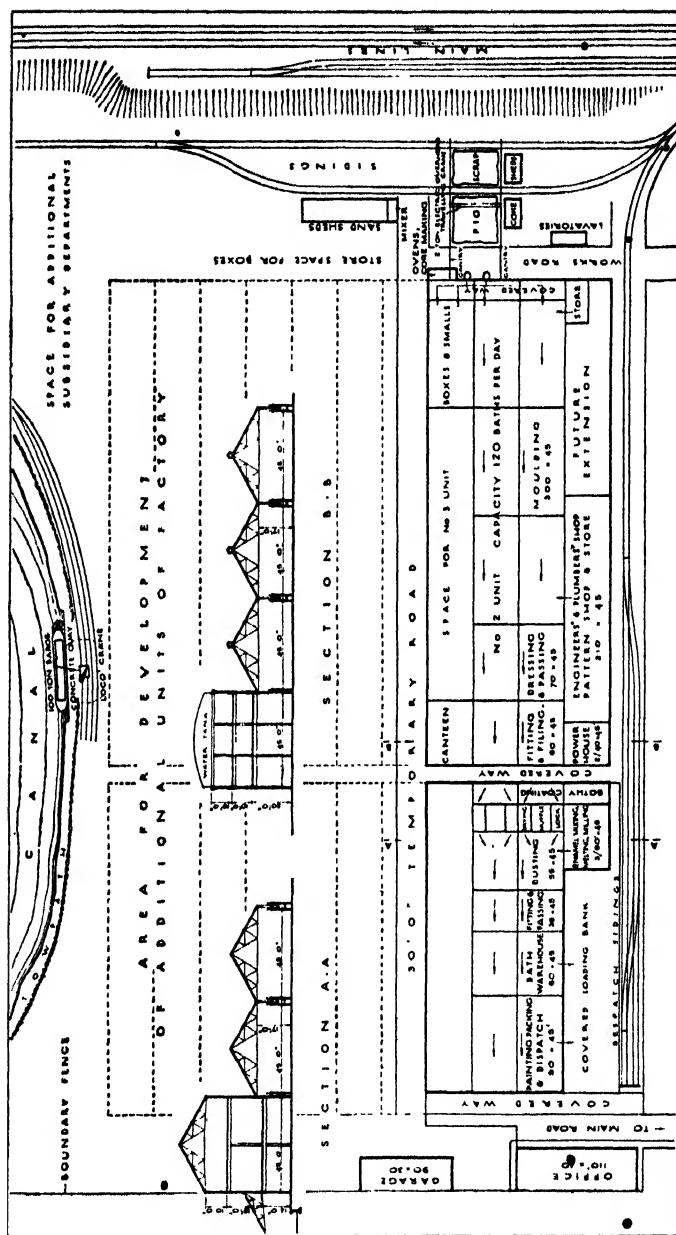
continuous production of 120 baths per day, so that merely by multiplying the number of bays the output of the factory can be increased to any desired multiple of 120.

In laying out each unit of this factory, the floor space was first calculated for the plant required in the various processes for the stated output, and by dividing by the length of the site the bay width was ascertained. The lay-out will be recognized as a good example of straight-line flow, the heavy raw materials which are canal-borne being stored at one end adjacent to the cupolas, and the product passing through the moulding, dressing and fitting departments, across the covered road, to the enamelling and finishing departments. The baths pass into the warehouse, from which they are taken, painted, packed and dispatched by either rail or road.

Adequate provision must obviously be made for economic expansion or the addition of supplementary processes. Equipment and processes involving dust and fumes or operations which are hazardous or noisy must be separated from the rest. The testing department may be taken as an example of one which must be kept free from noise and vibration. Fire hazards and general safety and the provision of ventilation, lighting and heating must receive attention. Finally, after consultation between the process engineer and an industrial architect, the lay-out may be completed by suitable buildings.

Efficient factory lay-out increases the capacity of a plant of given size, and is the foundation of economical production. Within a given floor space the lay-out may be the controlling factor in determining the effectiveness of the manufacturing enterprise.

It must be remembered, however, that there is no such thing as a stable ideal lay-out of either buildings or plant, and particularly in rapidly developing industries it is dangerous to plan the lay-out without flexibility in mind. One portion of a factory may have to expand without corresponding growth in other portions, but unless each shop



By courtesy of

FIG. 55. LAY-OUT OF A BATH FOUNDRY

Messrs. C. W. Glover & Partners

can "breathe" comfortably, a patchy lay-out may result and the fundamental plan be upset.

Assuming that the most suitable machine equipment has been installed in the most effective sequence, the work must be so planned that every machine is employed and the desired output achieved. As a rule, actual production occupies less than half the time taken to complete a given part, and the importance of convenience in handling and rapidity of transport will thus be appreciated.

FACTORY INTERNAL TRANSPORT

The great importance of internal transport as a factor influencing factory efficiency needs no emphasis. If it is inadequate it causes delays and limits productive capacity, constituting a "hidden" cost of production which in this era of narrowing profit margins may have serious effects.

The usual manufacturing cycle consists more in moving than making, so that attention should be directed to fitting the internal transport system to the production equipment so that they constitute a single unit. By materials being delivered as fast as needed, productive labour is made more effective and the unit cost of production is reduced.

The proper order of consideration of the factors governing the lay-out of a new plant is important. Materials-handling problems must be studied when planning the equipment and prior to erection of the factory, as internal transport arrangements will influence, if not decide, the size, design and construction of the buildings and even the site and future development of the plant. In continuous manufacture the entire process is built round the materials-handling equipment. In an existing plant, the selection of the most efficient internal transport system may increase output, speed up deliveries, decrease the manufacturing cycle and inventories, or in other ways decrease costs of production by smoother and speedier manufacture.

Co-ordination is the keynote in lay-out as well as in organization, co-ordination of the handling methods with

production equipment and the shipping methods. Consideration should be given to containers, skid platforms or special devices improvised to meet the requirements of the process. The product itself may have to be designed from the handling point of view, and in all these matters the safety of the operators and the "foolproofness" of the equipment must be borne in mind, especially in view of the large percentage of industrial injuries that are due to falling objects.

Many of the problems of mechanical handling are reduced or eliminated by a planned lay-out reducing moves to a minimum and having successive operations next door to each other. In any case the transport problem should be considered as a whole and not a number of small problems. Mechanical handling cannot correct a poor lay-out however badly it is needed to overcome transport shortcomings. Mechanical handling should not be used unless the quantity of goods to be transported, their size or nature, the distances covered, the saving of floor space, less likelihood of damage or some other factor justifies the expense and renders mechanical transport cheaper than manual means.

TYPES OF MATERIALS-HANDLING EQUIPMENT

Materials-handling systems may be classified into—

(1) lifting and lowering, (2) transporting, (3) a combination of (1) and (2); or alternatively into (1) overhead, (2) floor systems.

Mechanical handling is, however, so large a subject as to have acquired a literature of its own and cannot be dealt with here except by a reference to its scope.

The mechanisms include—

1. Cranes: jib, gantry, overhead travelling, locomotive, wharf.

2. Hoists: rope, chain, magnet, bucket, skip, drag-lines, winches, car handling.

3. Elevators and Conveyors: platform, tray, bucket, gravity, including spiral chutes, belt, push-bar, screw, pneumatic.

4. Overhead Carriers: tramrail, monorail, telpher, cableways.

5. Rail Conveyors: railways, storage battery, petrol, steam, compressed air, locomotives.

6. Trackless Carriers: petrol, storage battery, tractors and trailers.

7. Coal and Ash Handling Equipment: storage and weighing machines.

Considerable publicity is given to "conveyorized" handling with the refinements of speed reducers and photoelectric control on account of its elimination of waste motion, but it must be remembered that it is not as yet widely applicable in engineering work except for assembly processes. A "conveyorized" foundry is certainly a beautiful example of efficient materials handling, but in many processes it is not the most economic procedure. A recent analysis of American handling methods gave the following order—

1. Hand trucks.
2. Hand lift trucks.
3. Overhead cranes.
4. Monorails.
5. Miscellaneous conveyors.
6. Gravity conveyors.
7. Belt conveyors.
8. Industrial railways.
9. Hand labour.

SELECTION OF EQUIPMENT

The selection of internal transport depends on so many factors that it is impossible to make any recommendations without considering some specific problem. These factors include (1) the nature of the commodity handled, (2) the size, shape, weight and fragility of the product, (3) the production rate of the plant or the amount to be handled, (4) the distances to be covered, (5) the sequence of the processes and number of times materials, etc., are handled, (6) the possibility of increased speeds, (7) the type of container, if any, (8) the possibility of future expansion, (9) the location of assembly and testing, also shipping connections, (10) the first cost, (11) the maintenance and depreciation rates, and (12) the availability and cost of unskilled labour.

Every type of handling equipment has advantages under certain conditions, so that it is essential to review each method and select the most efficient for the purpose in view and the volume of work involved. Choice must be made of the methods which result in the least cost, but this means considerably more than the first cost. Apart from investment costs, upkeep and running expenses, provision for flexibility, failure and possible extensions have to be borne in mind. It is advisable to choose standard equipment where possible, and it is assumed that the possibilities of gravity feed have been explored before choosing power drive.

Emphasis has been placed above on the necessity for continuity of operation and for saving time in transport. With conveyors work can be performed on the product while it is being moved. The progressive assembly of gas stoves may be quoted as an example of cost reduction by conveyor work. It has been found that when ten or more operatives can be grouped for work, progressive conveyance of work will prove worth while.

A number of forms of conveyor have been devised, working with benches on one side or both, or without benches. They consist of belts of rubber, canvas, steel, or other material, or of slats which have the advantage that they can be used as lifts; in fact, progressive handling may vary from simple roller conveyors to elaborate special-purpose plants such as conveyors for electro-plating and oven or furnace work. Conveying has become a special branch of the science of planning manufacture.

The capital and maintenance charges of conveyors are sometimes quoted as lower than for trucks of equal capacity, but for non-continuous work or when the quantity to be moved is insufficient to keep a conveyor working, trucks have a universality of application as well as a possible economy in use. There are many designs and constructions of trucks for loading, unloading, tiering, etc., as well as transporting and the one best adapted to the kind of work in hand should be chosen.

Where a works consists of a number of buildings, a narrow-gauge railway between and through the shops possesses advantages. The use of overhead cranes in shops is too familiar to require further reference.

CHOICE BETWEEN TYPES OF TRUCKS

The operating costs of trucks may be represented as shown in Fig. 56.

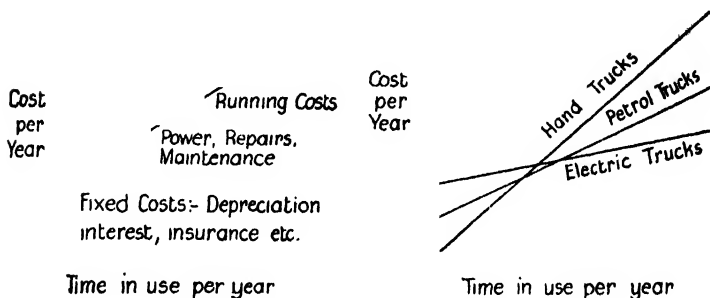


FIG. 56. OPERATING COST OF TRUCKS

The operating cost may be expressed by a simple formula---

$$y = \alpha + \frac{\beta}{x} + \gamma \frac{x}{s}$$

where α , β , γ are constants,

x is the length of haul and

s is the speed of the truck.

$\frac{\beta}{x}$ represents the cost of idling and

$\gamma \frac{x}{s}$ represents the cost of moving.

The period in use may decide which type of truck is most economic.

In general, the greater the period of use the more likely is the advantage to lie in the various types of trucks in the following order: electric truck, petrol truck, hand truck.

How soon will an installation pay for itself?

A simple treatment of the economics of a materials-handling equipment is as follows—

Let C be the initial cost.

The debit items as regards this investment are—

I = the percentage allowance for interest

M = the percentage allowance for maintenance and repairs

D = the percentage allowance for depreciation

R = the percentage allowance for rates and taxes

S = the yearly cost of power and supplies.

The credit items are—

Y = the yearly saving in direct labour cost

Z = the yearly saving in overhead

U = the yearly saving through increased output.

The fixed operating cost is—

$$C (I + M + D + R)$$

The maximum investment justified is—

$$\frac{Y + Z + U - S}{I + M + D + R} \times p$$

(p = the percentage of the year the equipment is used).

The yearly profit from the investment is—

$$(Y + Z + U - S) p - C (I + M + D + R)$$

and the percentage annual saving is obtained by dividing this by C, from which can be calculated the time required by the installation to pay for itself.

COST REDUCTION BY MECHANICAL HANDLING

It has been emphasized above that moving time is idle production time. Among the ways in which mechanized internal transport assists in cost reduction, especially when it can be made a pacemaker for the productive machinery, the following may be mentioned—

The period of the production cycle is lessened, output is increased, unit transportation cost is reduced ;

' Stock holding is reduced to a minimum (examples are known where stock holding has been reduced as much as 70 per cent) and a quicker turnover of invested capital is obtained;

Floor space is conserved, and reorganization, regrouping and concentration of machines facilitated;

A steady flow compels teamwork, time-keeping is mechanized and production control facilitated;

Integrated and synchronized production is possible and limits are removed from production size.

CHAPTER IX

BUILDINGS AND FIXED EQUIPMENT

ENCLOSURE of the production lay-out results in buildings, the type being decided by the kind and quantity of product and the class of materials handling and equipment necessary. For a factory building scheme there will be need to use the services of an industrial architect, as a distinctive modern type of architecture has arisen, combining simplicity with sound and permanent construction. With a view to specializing and adapting buildings and shops, the engineers of the factory must naturally co-operate, as there are certain matters which they alone can settle.

PROVISION FOR EXTENSIONS

Ease of extension of buildings results from having their plans or floor areas initially in the form of some letters of

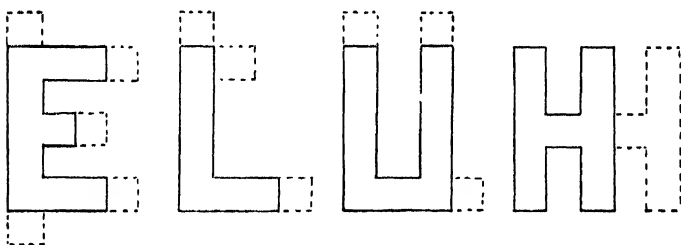


FIG. 57. PLANS FACILITATING EXTENSIONS

the alphabet, e.g. H.L.E. These permit extension in several directions from end walls whilst ensuring light wells for adequate daylighting.

Adaptability must be borne in mind not only in plan but in construction.

FOUNDATIONS

The foundations of buildings call for particular attention. They must be sound and adequate for the superstructure,

especially for buildings subject to the constant vibration of machinery. The bearing power of the ground must be ascertained. If artificial foundations are required, reinforced concrete in the form of piles or rafts has been found very satisfactory for the purpose.

It may be advisable to consult experts on questions of the prevention of transmission of vibration and noise. It is cheaper to take precautions than to cure the nuisance afterwards. Not only can machinery be isolated but sound-proof buildings and structure can be designed if so required.

Having laid down a comprehensive plan adequate for immediate needs and permitting extensions, the points that arise for consideration include the following: the type of construction of the various departments, the floor materials and the number of floors if the buildings are not all of one storey, the supports for cranes and shafting, the methods of fire protection, ventilation and heating, the distribution of power and artificial light, the arrangements for laying lines for water, steam, gas, compressed air, and the various special problems arising from the particular type of manufacturing plant.

METHODS OF CONSTRUCTION

The principal considerations with regard to structural materials are strength, durability, safety, stability, speed of erection and cost. The number and range of materials available for factory buildings are large and varied, and need careful selection to obtain those most suitable to the specific requirements of the plant. The buildings may be of brick, with or without steel frames, or of concrete blocks, or reinforced concrete. Special manufacturing operations call for departure from the ordinary type of construction. Galvanized sheets may be used for light types of structure. Bricks are relatively cheap but costly to erect and are being largely replaced by concrete which has caused much change and development in factory buildings.

Steel-framed construction is almost invariably used in single factory building. Not only has the use of structural steel and steel joists increased for factory buildings but the all-welded steel frame construction is now available.

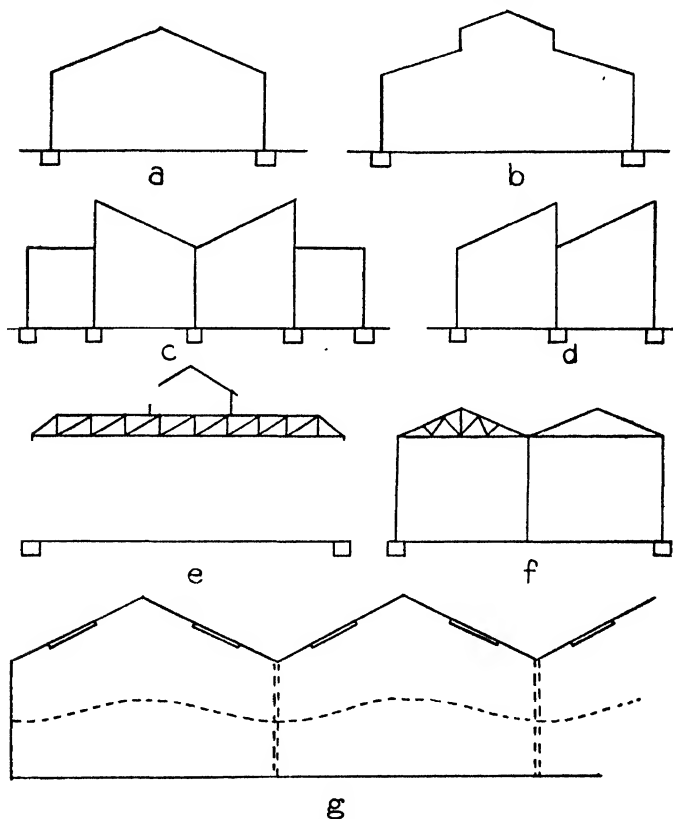


FIG. 58. SECTIONS OF STEEL FACTORY BUILDINGS

In bay construction the span is determined by the floor area required for the most convenient unit of output in relation to the length available. The M-shaped roof shown in (c), Fig. 58, is suitable for foundries owing to the good natural draught.

Reinforced-concrete structures are quickly erected, low in maintenance cost, fire resistant, and very strong. The advantages are, however, offset to some extent by the cost of subsequent alterations to the building.

This material of construction is particularly useful for multi-storey buildings. One storey may be added above another in a sort of mushroom construction as shown in (c), Fig. 59, below.

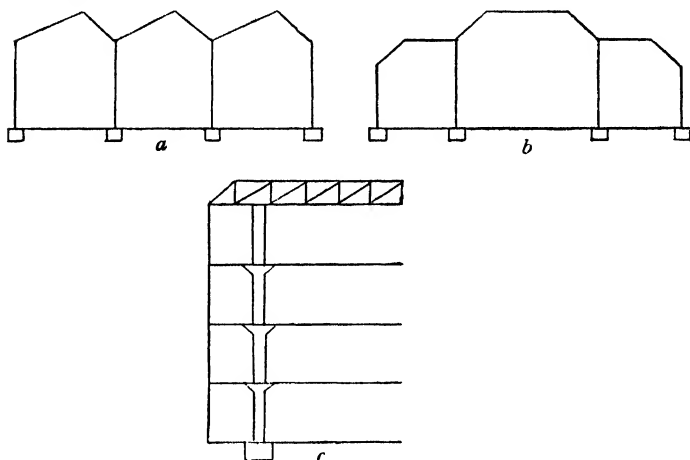


FIG. 59. SECTIONS OF REINFORCED-CONCRETE BUILDINGS

It should be noted that all factory buildings must comply with the Factory and Workshop Acts, and should be in accordance with the fire insurance office requirements and the local by-laws.

WALLS AND PARTITIONS

Many special materials are available for wall construction: rendered cement, asbestos cement, synthetic fibre boards, insulating blocks, and metal steel construction of various kinds. Their costs must be considered in relation to the advantages for the factory in question. For factory partitions and screens, the chief desiderata are cheapness

and rapidity of erection. They may consist of asbestos-cement sheets, plaster or breeze slabs, or plaster board. Doors may be top-hung for ease of opening and automatic closing, but in certain cases must open outwards to comply with the Factory Acts and fire protection requirements.

ROOFS

Roof coverings must be light and cheap but durable, resistant to the weather and bad conductors. It must be remembered that the heat loss from a factory roof is about 50 per cent of the total.

Saw-tooth roofs will be referred to below in regard to daylighting, but it may be mentioned that roof-glazing largely consists of $\frac{1}{4}$ in. rough cast or wired glass. The longer slopes may be flat or corrugated steel sheets or even concrete slabs. Spans are built up to 60 ft. Concrete buildings usually have flat roofs which may be of the same material, lead, zinc or asphalt.

Roofs must be adequately drained, and a point which well repays attention is care in gutter construction. Steam pipes may be carried along in the neighbourhood of gutters if they are likely to freeze.

FLOORS

Floors may be made from a variety of materials, from a sand floor to polished wood blocks—the type depending on the nature of the factory processes. Efficient flooring should possess a number of qualities, including durability, low thermal conductivity, silence, non-slipping properties, freedom from dust, ease in cleaning and repairing and low cost, but commensurate, of course, with the life or convenience expected. In making a selection between alternatives the materials should be rated under these or other headings with a view to choosing the best all-round material for the factory in question.

Boarded floors are still widely used, or wood blocks on

concrete foundations, especially where there is a danger of dropped parts being damaged. Where the traffic is heavy a hard dustless floor is required and a granolithic finish gives good results. An asphalt floor wears poorly, but is easily repaired, and is good for wet situations or where acid may be spilled.

Metal floorings resist wear indefinitely but are light, conductive, and may be noisy. Chequered steel plates are safe and non-slipping. Water-cooled floors are necessary for special machinery, e.g. in rolling mills.

Many different tiles are available for tiled floors where necessary. They are easily cleaned, but are cold, and may crack and be difficult to repair. Alundum tiles are non-slipping and provide an alternative for dangerous positions, e.g. in front of machinery and on treads of stairs.

Before laying floors thought should be given to the passage of conduits and the holes through which pipes are to rise.

SINGLE-STOREY AND MULTI-STOREY BUILDINGS

Industrial buildings are designed to perform a functional purpose and this will decide the type of building, e.g. if the manufacturing methods involve the gravity flow of products as in the manufacture of chemicals and paints, a multi-storey building is indicated, but for heavy work and products a single-storey building must be used. In the latter case, as in locomotive building, the vertical flow of materials is ruled out.

Where either type of building is permissible, an economic choice must be made by balancing the advantages against the disadvantages. With regard to the site, for example, it is evident that for a given capacity the area of a single-storey factory must be greater than that required for a multi-storey factory, and, if land is dear, the latter will have an advantage in the cost of the site. As it is usually stated that a single-storey building is most suitable when space is available, let us examine the advantages of this type—

1. Lighter foundations ;
2. Less subject to vibration troubles ;
3. Supervision easier and more effective ;
4. Greater efficiency in routing and handling materials ;
5. Greater flexibility with regard to lay-outs ;
6. Less fire hazard—lower insurance charges ;
7. Greater ease of isolating dangerous processes ;
8. Simpler methods of expansion ;
9. More effective floor area, free from columns ;
10. No stairways, fire escapes or question of floor loads ;
11. Better natural lighting—even top light ; therefore width is not limited ;
12. Lower cost of artificial light ;
13. No power required for lifts and elevators ;
14. A mezzanine floor will provide additional office or shop space.

On the other hand the cost of heating and ventilating may be higher, the cost of roof maintenance will be more, longer ground runs are required for drainage, distances may be excessive for the transmission of mechanical power, there will be less convenience for water storage as compared with a lofty roof, and cleaning of window and glass-lights will probably be more expensive.

On the whole, however, single-storey buildings are less expensive and there is a general tendency to use them, except in light engineering works where the machines and products are readily adjusted and handled in accordance with the floor arrangements.

FIRE PROTECTION

The chief safeguard against fire lies in the use of fire-proof construction. Fire prevention is more important than fire combating. Factory buildings should, wherever possible, be built of fire-resisting materials, e.g. steel construction and ferro-concrete. This also applies to party walls and partitions. Exits should be provided with panic bolts and should swing or open outwards. External fire staircases

should not pass by windows. The doors in party walls should also be of reliable fire-resisting materials. Double doors give an added advantage. Inspection is, of course, necessary to ensure proper functioning at all times. Lifts and hoists should be enclosed in a brick or concrete well and have fire-resisting doors. Superheated steam pipes should be suitably lagged where they pass through or near wooden partitions. The equipment in cloakrooms should be of steel. Special attention should be given to insulating those parts of a factory most subject to fire hazard with a view to minimizing the risk of spreading.

Fire-proof construction, fire extinction and escape from fire are inextricably connected. It is essential, for example, that staircases be made of fire-resisting material.

The principal fire-resisting devices depend on an adequate and reliable water supply. A ring main should be constructed to pass conveniently near to each building. Two sources of supply are desirable and in each case the pressure should be adequate.

Automatic sprinklers and drenchers should be fitted throughout the shops. If freezing is probable the dry-pipe system may be employed, the water being kept back to the supply pipe by compressed air. Each installation should be fitted with an automatic fire alarm. Valves should be fool-proof and the system of fire extinction tested periodically, especially fire hose which may deteriorate unless under constant supervision. The maintenance of fire equipment may be overlooked from a feeling of security; chemical extinguishers should be kept in accessible positions with clear instructions for use.

Special precautions should be observed if combustible and inflammable materials are used and stored.

Inflammable spirit, for example, should be stored below the level of the ground to prevent spreading. Buildings should be constructed of asbestos slab and kept properly ventilated to prevent overheating or spontaneous combustion.* It is known that the latter phenomenon may occur

in large heaps of coal, so that if coal is stored in quantity arrangements should be made to take the temperature of the heaps periodically.

The danger of the spontaneous ignition and explosion of dust is well known, so that in processes where dust is generated special precautions should be taken for its extraction and bare flames absolutely prohibited. In particular, hot water pipes and radiators should be kept free from dust. The generation of static electricity should be guarded against or, if unpreventable, the atmosphere should be kept humidified and the machines earthed. Inflammable rubbish and waste should be placed in specially constructed bins.

Not the least important point is to know what to do in case of fire and who is to do it. The responsibility for fire protection should be upon the works manager, who should see that the fire brigade authorities are conversant with the position, organize a fire squad adequate to deal with the situation until the brigade arrives, and ensure that the employees are properly educated in regard to procedure in case of fire. Fire instructions should be absolutely clear and practical, including what is to be done to the machinery, windows, doors, gas and electricity supply, etc., should the alarm sound. Instruction should also be given in the use of chemical extinguishers, buckets, blankets, first aid, etc.

POWER SUPPLY

It was stated in Chapter VIII that electrical supply, if the grid system is available, presents no difficulties, but if the supply company is a private concern it may be necessary to see that the supply is adequate at all times to meet maximum demands, and at the required voltage. Every plant requires power at the minimum overall cost per unit, and whilst in most cases it may be economic to purchase from a supply undertaking, there will also be plants in which the cost of generating should be considered. This alternative depends mainly on the nature of the industry

and the size of the firm, and whether large quantities of steam are required for process work. Among the principal advantages of central station generation are the lower percentage of spare plant required and the better load factor compared with private plants. On the other hand, the line losses in transmission over a wide area may be appreciable and there is also the cost of sub-stations for transformation, whereas in a factory the energy is generated in the desired form at the point of utilization.

In considering the erection of a factory power-station one must first ensure adequate water-cooling facilities, then deal with the size and nature of the load and the continuity of supply. The site of the power-house requires attention with regard to fuel and ash handling problems and so as to minimize the length of distribution lines. This will also minimize steam distribution lines and compressed air pipes.

There is much to be said for taking current from a public supply undertaking, but the alternative policy is not invariably wrong. Fuel may be exceptionally cheap in some parts, or process steam may be required in abundance in some works. Self-contained pass-out turbines appeal strongly in such industries as paper making, woollen and worsted industries, and the production of chemicals.

The gradual obsolescence of existing private plants will no doubt reflect favourably upon the supply undertakings, but in any case the conversion from private generation to public supply, involving perhaps the installation of new motors or the provision of converting plant, must be a gradual process. It is not likely that all manufacturers who have recently installed oil-engine sets have made a great mistake. With light high-speed engines the capital costs are lower than the older, heavy, slow-speed sets and oil consumption has been considerably decreased.

Little attention has, on the whole, been given in this country to the possibilities of gas engines, but if gas grids develop, such engines may be more used for generation as,

for example, in Germany. It may be noted that the total capacity of motors supplied by private plant increased from 1924 to 1930 by 28 per cent, whilst that of motors driven by purchased power increased 48 per cent.

METHODS OF APPLYING POWER TO MACHINES

There are four principal methods, viz., by belt, gearing, silent chain and direct motor drive. The individual drive has increased greatly in use, being more flexible and convenient in case rearrangement of the lay-out is desired. The motor must, of course, be of sufficient capacity to carry the maximum load of the machine, but full load will not be required for part of the time. The group drive is therefore frequently more economic, not only in installation cost but in power consumption, as it is most unlikely that the peak loads on all machines will occur together and the larger motor may be more efficient. In all cases the possible economies in power must be weighed against any disadvantages in production arrangements.

There are a number of economic problems in the choice of an electric motor. Price has to be considered against quality and the choice of high efficiency is usually sound economically, as the energy saved thereby may more than repay the cost of the motor. A larger machine than is necessary on physical grounds may give advantages owing to higher efficiency. The possible economic advantages of under-running require careful investigation, especially where energy is dear or the load-hours high, quite apart from over-specifying to cover possible overloads.

HEATING AND VENTILATING

The economic selection of the heating equipment depends on the same factors as for any other equipment, viz., the balancing of investment costs against operating costs but bearing in mind the comfort and therefore the efficiency of the operatives. The greater the period of the year during which the system is in use, the higher the initial investment

justified. The systems generally employed are pipes and radiators heated by water or steam and unit heaters usually electrically heated. If a factory has a supply of low-pressure steam which would otherwise not be utilized, the operating costs of steam-heating the factory are, of course, low. On the other hand the use of unit heaters is increasing, as they may be conveniently placed where most needed. Electric heaters may be suspended so as to direct a stream of warmed air downwards or placed on the floor and thermostatically controlled, but in any case a continual circulation is developed.

Good air conditions are conducive to health and efficiency. Bad ventilation results in lower output and quality, increased sickness and accident frequency, and affects labour turnover. Comfort is due to a physical function of the air rather than a chemical one. Its cooling power is due to its temperature and velocity of circulation so that the air must be properly introduced and uniformly distributed through the shop. About 30 to 50 cub. ft. per workman per minute are required or the air in the shop should be changed about six times per hour, depending on the outside temperature.

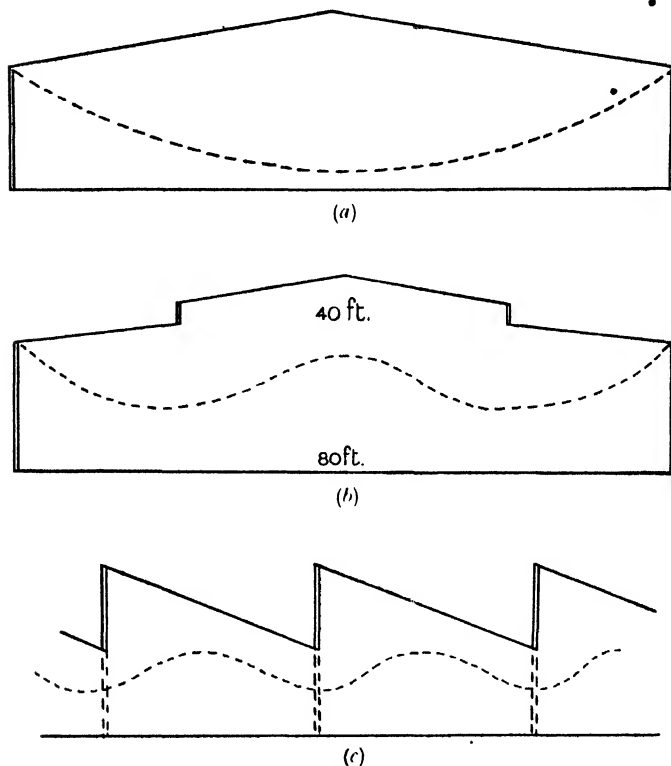
There are two systems of ventilation, viz., natural and forced. The former utilizes the normal movements of air currents, warm air leaving at or near the roof. In the latter system, mechanical equipments (fans) pull the fresh air into the shop, in some cases after it has been conditioned (filtered, cleaned and humidified), and distribute it where required. Frequently a plenum system is employed consisting of a main trunk line and lateral branches or ducts.

Contaminated air, dust, odours and fumes must be removed by exhaust systems from, for example, enamelling and spraying rooms, foundries and glass-making, chemical and lead works.

ILLUMINATION—NATURAL LIGHTING

Adequate daylighting must be provided for, cloudy days being taken into account.

A factory may derive its light from side windows or from the roof or both. With lighting from side windows the illumination falls off rapidly towards the centre of the



SHOP SECTIONS

FIG. 60. LIGHT INTENSITY CURVES
(SCALE NOT SHOWN)

shop, the working space, when lighted from both sides being roughly three times the height of the window (see Fig. 60(a)). Lighting is improved by increasing the size, especially the height, of windows, which accounts for the fact that in some factories as much as 75 per cent of the

wall area consists of glass. Prismatic glass and Vita glass are usually too expensive for factory use. In wide shops the intensity of illumination in the middle is augmented by the use of monitor windows (Fig. 60(b)), the best width of the monitor being one-half that of the building. The total glass area wide side windows should be about 30 per cent of the floor area.

Roof illumination, with the north-facing saw-tooth type of structure (Fig. 60(c)) also gives fairly uniform intensity.

Care should be taken to see that adequate provision is made for cleaning windows, as they may lose 50 per cent in efficiency from six months' dirt.

Even under the best conditions natural daylight can be depended on during only a relatively few months of the year and artificial light is usually required for some part or all of the day.

As the natural lighting becomes inadequate a point is reached for which the term "grumble point" has been coined, after which artificial lighting becomes necessary, and the discretion of the shop foreman should be such that the lights are on just prior to reaching the grumble point, and that false economy is not practised by trying to cut down the light bill.

ARTIFICIAL LIGHTING

Good artificial lighting in a factory is a cardinal factor in maintaining the normal output during lighting hours. Poor lighting imposes a continual physical and mental strain on the operatives, depresses them, and acts adversely on their health.

Lighting requirements must be based on the visual demands of the work. The misuse of high-intensity lighting is bad illumination just as much as insufficient light. Special attention should be given to the lighting of stairs and passage ways.

Electricity has gradually displaced gas for lighting purposes, but the modern improvements in gas mantles, use

of high-pressure supply, and preheating gas in burners have resulted in a high standard of illumination by gas which is still used for outside lighting.

Accidents are caused when operatives are unable to see clearly what they are doing. The ability to see an object depends on size, contrast, brightness and time of exposure. With low intensities of illumination a relatively long time is required for perception, too long, for example, to prevent the occurrence of an accident. As illumination increases the time required for perception is reduced, e.g. at 10 foot-candles illumination the eye takes only two-thirds of the time to perceive an object that is necessary at 5 foot-candles illumination.

Glare or excessive contrast in brightness is a common fault in industrial lighting, especially direct glare. It defeats its own object, as the eye cannot take advantage of the illumination provided. It reduces seeing power and gives rise to discomfort, headaches and nervous effects. More accidents occur through glare than insufficient light.

Flickering caused by objects passing the sources of light should be avoided as it causes the eye to tire. Where a stroboscopic effect occurs, protective or warning devices should be used.

ECONOMIC VALUE OF GOOD LIGHTING

Good lighting means that not only is the intensity of illumination adequate but that the light is correctly applied. Poor lighting lowers the speed of working and therefore the output per man increases the percentage of scrapped work, is a fruitful source of industrial accidents, and undermines the morale of operatives.

Exhaustive tests have been made to determine the relationship between intensity of illumination and the speed and accuracy of operatives. In one case of detail work efficiency with an intensity of 20 foot-candles was the same as in daylight. As an extreme case intensity was reduced to 2 foot-candles, and it was found that output was

reduced 25 per cent and the number of errors increased 100 per cent.

The true economic value of good illumination is not determined by comparing the improved production with the installation and maintenance costs as all the gains, e.g. in comfort, cheerfulness and cleanliness, cannot be measured in terms of £ s. d. Compared with other charges that for lighting is relatively so small that it may be said that good illumination always pays for itself.

TYPES OF LIGHTING INSTALLATIONS

The systems usually employed in industrial buildings are—

1. General overhead lighting, which is satisfactory in the majority of cases, is the least costly and maintenance charges are also low. No changes are necessary if there is an alteration in lay-out of the plant.

2. Localized overhead lighting. Fittings are arranged in groups to illuminate large plant or machinery interfering with the general overhead system. Rearrangement of plant will, of course, necessitate modification.

2. General lighting combined with local lighting. This system is required where high intensity of illumination is demanded for fine or detailed work. The local lighting is, of course, supplementary to the general system.

4. Special lighting problems may arise with unusual plant, in which case it is usually best to seek the advice of an illuminating engineer.

When local lighting is necessary the fittings should be mounted on adjustable arms either attached to the machine or standard on telescopic bases.

The steps in the design of a lighting system comprise—

1. Decision on the foot candle illumination required.
2. Selection of the most suitable type of fitting.
3. Determination of the location, number and mounting height of fittings.

4. Ascertainment of the size of lamp required to give the illumination.

5. Allowance for the room or shop index.
6. Allowance for the coefficient of utilization.
7. Allowance for the depreciation factor.

1. A good deal of work is required to ascertain standards of good practice for different classes of industrial operations and shops. The desirable intensity of illumination varies with the nature and accuracy of the work, fineness of detail, colour of materials handled, and so on. The following intensities are recommended for machine shops.

Rough Bench and Machine Work	.	.	.	7-10 foot candles
Medium Bench and Machine Work	.	.	.	11-14 foot candles
Fine Bench and Machine Work	.	.	.	15-20 foot candles
Extra Fine Bench and Machine Work	.	.	.	25-50 foot candles

2. Having decided whether the lighting is to be direct, indirect or semi-indirect, the following points should be considered in choosing fittings.

(a) Is the illumination required for sustained vision on flat surfaces on the horizontal or slightly oblique planes?

(b) Is the illumination required on vertical planes in addition to horizontal, as for example in machine shops?

(c) Direct glare must be avoided.

(d) Reflected glare must be avoided.

(e) Where shadows are desirable they must be soft and luminous.

(f) The fittings must be of such a construction that they are easily cleaned, dust-tight and not liable to breakage.

The relative importance of the above must be decided for the illumination scheme in hand, e.g. for a machine shop it is suggested they are in the following order—*c, d, a, b, e, f*.

Many scientifically designed lighting fittings are available for industrial purposes. Usually they are robust enough to protect the lamps without special wire guards and they can, if desired, be rendered acid and fume proof.

Vitreous enamelled steel reflectors are generally suitable for general overhead lighting, the dispersive distribution of

light giving adequate illumination on both horizontal and vertical planes.

For fine assembly shops, drawing offices and so on where a high intensity is required without glare, a diffusive type of fitting with an opal glass bulb surrounding the lamp is recommended. Concentrating reflectors may be used when mounted high above the plane of work, e.g. above travelling cranes. Angle reflectors may be employed to augment an overhead system to ensure well-lighted vertical systems.

3. To secure even illumination light fittings must be arranged symmetrically and not too far apart, the spacing depending on the mounting height. The lay-out will depend on the position of obstacles such as columns, shafting, etc. The higher the mounting the fewer the fittings required for uniform illumination. The distance from a wall to a fitting should be from one-half to one-third of the spacing distance.

4. The size of lamp may be calculated as follows—

Lamp lumens per fitting =

Foot candles illumination multiplied by the area to be illuminated per fitting multiplied by the depreciation factor and divided by the coefficient of utilization.

It should be remembered that for large gas-filled lamps the efficiency—i.e. lumens—output per watt input, is higher than for smaller lamps and where conditions allow for such lamps, the former should be used, as better illumination is obtained for the current consumed.

5. The room or shop index depends on its size and shape and the height of the lamps above the plane of the work.

6. The coefficient of utilization is the proportion of the light produced from the lamps which reaches the plane of the work and varies with the proportions of the room, the colour of the walls, the ceiling and the machines and the type of fitting.

The reflectivity of side walls is usually about 50 per cent and of ceilings about 70 per cent, but depends, of course, on the colour.

7. The depreciation factor is the allowance made in extra

initial illumination to compensate for deterioration due to dirt, dust and ageing, usually about 30 per cent.

An organized system of maintenance is essential to prevent deterioration. Enclosed fittings may depreciate, 20 per cent in two months from dust and dirt, so that all lamps and fittings should be cleaned every four to six weeks. Detachable deflectors facilitate this work. Maintenance of an outside lighting system is always higher than that of interiors but is important for the prevention of accidents in yards, entrances, etc. The roof structure of a factory will generally decide the lay-out of the lighting system, the fittings being mounted on the beams or girders. Detailed lighting schemes for different kinds of shops will not be given here, but attention is drawn to the necessity for well lighting the stores, a point frequently neglected and resulting in much loss of time. Standard dispersive reflectors down the gangways between the bins are satisfactory in many cases.

PLANT MAINTENANCE

The contribution of the plant department to the efficiency of a works needs no emphasis. If a breakdown occurs production stops and the work of the planning and progress departments is dislocated, so that the work of the maintenance engineer is vital in achieving the production schedule.

It has been previously indicated that maintenance is a struggle against deterioration from wear and tear of plant in use. Unless plant is kept in efficient condition, the rate of production slows up and increased costs result. The work of the plant department cannot guard against obsolescence, but by preserving the fixed assets in good working order it enables them to operate at full load and earn a maximum income with a view to the early establishment of a replacement fund.

DUTIES OF MAINTENANCE ENGINEER

The duties of the maintenance engineer may vary according to whether he is in a large or a small engineering works,

but in any case the closest co-operation with the production manager or works manager is involved.

This work may be divided as follows—

(a) Buildings and grounds. He may be concerned with the erection, extension and supervision of buildings, their fire protection, heating, ventilation and illumination; also water supply, drainage and sanitation.

(b) Power generation and distribution: boilers, engines, turbines, motors, wiring, lamps; the supply of gas and compressed air.

(c) Production machinery: its installation and maintenance.

(d) Service machinery: internal transport. The plant engineer may be concerned with its design as well as maintenance.

(e) Safety provisions throughout the plant.

The maintenance engineer should, of course, sit on the executive production committee. This will ensure that in the purchase of machinery, for example, full importance will be given to the question of accessibility, a point frequently overlooked by the staff responsible only for output.

INSPECTION AND RECORDS

The duties of the plant engineer being preventive rather than corrective, attention is mainly given to the anticipation of distress in machinery. To this end a routine of periodic inspection and reports is established. Inspection intervals may vary from daily to annually according to the part of the plant in question.

The plan of inspection should be fixed beforehand to ensure that it is carried out at the most convenient time and to avoid interruptions of work. Planning tables of maintenance work systematize the work, and the dates at which various machines are to be checked are seen at a glance.

When the time-table indicates that an inspection is necessary an instruction work card is filled in and issued to the man doing the job.

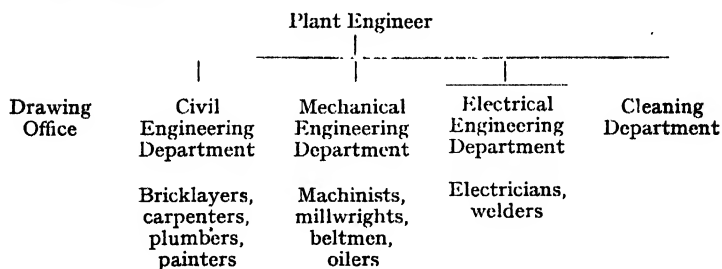
The inspection book of suitably printed forms indicates each item of plant, the inspection period, what to do, the report, and the instructions issued and performed. It will be recognized that these records also have a value in connection with any cases that may arise under the Workmen's Compensation Act.

A separate record of breakdowns is kept. In the event of a breakdown the plant engineer's duty is, of course, to restore the interrupted service at the earliest possible moment so as to reduce idle time to a minimum.

A measure of the efficiency of the department is not necessarily its cost, but, in accordance with the above, may be taken as the percentage of repair jobs done in an emergency. If the efficiency of the plant is estimated as the ratio of the actual productive machine hours to its machine hours capacity, the efficiency of the plant engineer can be taken as the ratio of the actual productive machine hours to the sum of the actual productive machine hours and the idle machine hours due to breakdown.

ORGANIZATION OF MAINTENANCE DEPARTMENT

In the organization of the maintenance department there must be a clear definition of responsibility for the work to be done and the results desired. A suggested organization is as follows—



The engineer, mechanics, and workmen must have good qualifications and experience, and be picked for sound work

and reliability. Their remuneration should be somewhat higher than correspondingly qualified men on the production side on account of the need for reliability and the night and week-end work to be expected.

Whilst it conduces to efficiency to organize a central maintenance and machine inspection department, the charges should be debited to the departments using the plants and machinery so that they feel the responsibility for the cost of repairs and maintenance.

Requests for the services of the department may be oral or written as there is no time to waste in case of an urgent repair. Apart from this, however, orders should be made out for the use of the maintenance department's services. In the case of routine services, standard costs will have been established, but for such jobs as the installation of new plant estimates must be made and sanctions obtained.

When repair jobs are completed the costs are established from the materials used and the time cards of the repair mechanics, and compared with the budgeted or estimated costs.

BUDGETING FOR MAINTENANCE

The work of the plant department must not only be planned ahead but the results obtained examined periodically. It is recommended to have the plant engineer prepare a yearly budget or forward estimate of the expense to keep the factory in running order. This budget may be arranged under expense headings of repairs, replacements, improvements and additions or a classification to meet the factory's special conditions. The report must, of course, be intelligible to the financial experts as the cost accountant will need to analyse and criticise it. Monthly plant conferences should be held at which the maintenance work is reviewed. A report should be presented on the work completed in the last month and the programme of jobs to be undertaken during the next month should be tabled for discussion.

THE PLANT ENGINEER •

Reference has been made above to the necessity for co-operation with all departments. The production department will, of course, welcome it, as the work aids and sustains the output and lowers production costs. The production men appreciate tidiness and cleanliness of the plant and the reduction to a minimum of corrosion and friction losses.

The plant engineer will naturally co-operate with the Factory Inspector and take a prominent part in the work of the Safety Committee.

The plant engineer must not be overwhelmed with routine and detailed work but must have time to plan and develop fresh ideas. It has been suggested that he should budget for himself and it is assumed that he maintains graphical control of the work and expenditure of his department. He should have time to follow the leading technical papers and journals of the engineering institutions and also to visit plant exhibitions. This will serve as an insurance against obsolescence of his own plant.

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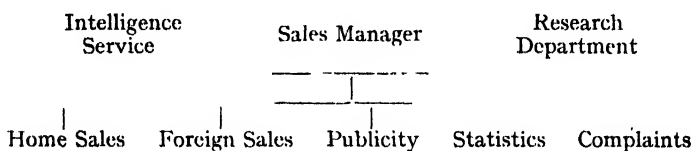
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CHAPTER X

SALES ORGANIZATION AND TENDERING

AN engineering sales department is a complex and variable organization with internal and external functions. In accordance with the general rules laid down for good organization the exact scope of each individual's duties and activities should be known to all. The general lay-out of the sales organization will be somewhat as follows—



The sales manager will, of course, take his policy from the board of the company, but he must be a man of initiative, ready to propose new policies as opportunity offers. He must be active, energetic and persistent in order to cope with the onerous work of sales promotion, which consists in exploring the possibility of obtaining new customers and markets and discovering new products to be manufactured, as well as consolidating his position by retaining accounts. He must be an energizer, heartening and putting fresh life and interest into his sales staff confronted with resistance difficulties, as they well may be, for example, in the face of severe competition.

It is essential that the sales manager be a good judge of human nature, a good "mixer," and know how to handle men—not only clients and prospective customers but also his competitors whom he will be meeting at trade and association meetings. He must understand the psychology of the industrial groups to whom he sells. He must be a good organizer, otherwise he will be unable to tackle the

hard work required to utilize fully the efforts of resident and travelling representatives and agents both at home and abroad, with whom he must keep in close personal touch. It is a good practice to have meetings of all representatives at the works at regular intervals when they can be instructed in the latest sales position, policy, and requirements, as well as bring themselves up-to-date in knowledge of the firm's products and capabilities.

Whether the sales manager should also be a technician is a difficult question. There is only one test of salesmanship, and that is to sell. The primary duty of the sales manager is to get results, and there are so many factors in salesmanship besides knowledge of product that too much weight must not be given to technical qualifications. Many non-technical men are successful sales managers of engineering firms, but owing to the increasing technicality of business, it seems advisable for the higher control always to bear in mind the advantages that might accrue from training and promoting a young technical man who can demonstrate an aptitude and flair for salesmanship.

A further requisite of the sales manager is helpful co-operation not only with the accounts department but with the works.

A special reference should perhaps be made to co-operation with the progress department. The latter is, in a way, the servant of the sales department. From a commercial point of view there is no virtue in merely producing an article; it does not effectively exist until it is in the hands of the user or customer. Some firms have a delivery clerk in the sales office whose duty is to keep track of delivery promises, advise the works departments of the urgency of the sales department's requirements, and peg away to see that promises are kept in the despatch of work. This clerk's work is superfluous with a properly organized progress department, as discussed above (Chapter V). Progress work requires a specialist and a man of standing in the firm. However persevering the clerk referred to

might be, the works would probably go their own sweet way. If the firm has a live and efficient progress manager, the sales department can get all the information it requires for correspondence or handing on verbally to customers by merely lifting the telephone and asking him. The sales manager places before the progress department the customer's point of view, and the progress manager endeavours to meet it, or, if impracticable, is able to say what is the best that can be achieved, and it is then the duty of the sales department to translate this into terms understandable by and acceptable to the customer.

PUBLICITY AND PROPAGANDA

Engineering publicity is a highly specialized activity. The sales manager will decide the selling policy and the sales campaign, though he will not do the detailed work of advertising and circularizing.

Until recently, technical advertising was somewhat awkward, hesitating and amateurish owing to insufficient study of the persons to whom it was addressed and its precise purpose. Purchasers of engineering products are usually technical experts or under scientific and technical control, and to approach them it is necessary to adopt means that will appeal to the technical mind. Claims that cannot be substantiated must be avoided, and only such information presented as is based upon careful tests and accurate research. Purchases are made only at fairly long intervals and after careful investigation, so that whilst the design and careful lay-out of advertisements are important, it is convincing technical information which induces action. The results of tests and technical diagrams are usually read with interest. It is a mistake to put a deal of copy in an advertisement, as it is confusing, but care should be taken that the name of the firm is unequivocally associated with the product. A bold, sure handling of advertising gets people to believe in the firm's products. The greatest appeal in advertising is the economic one, as technical products are

bought on their cost per unit of satisfactory service; in other words, engineering products are sold exclusively on their utility and economic advantages.

A demonstrated or proved effect on production is a good selling point in engineering advertisements.

As between standard products and specialities it is advisable to emphasize in the first case any proof of superiority over other makes and in the latter any proof of advantages in service.

An important medium of advertisement is the technical journal, which is a clearing house for news in a particular industry. The advertisements need only interest those who can influence the purchase of the products, but it will be found that impartial descriptions of products and plants, and details of installations and unusual applications, are of interest to those engaged in the industry who look through the advertisements to keep up-to-date in improvements and implement their knowledge of the trade.

Another valuable medium is the firm's catalogues and data books. These are tending to become treatises and books of reference. The effect of booklets, folders and bulletins is not so transitory as that of journal advertising, and they are in some cases sought after by users of the particular class of product as they give data and particulars of practice long before they can get into technical textbooks. They have the advantage that they can be sent direct to prospective customers and give confidence to buyers by demonstrating how exhaustively and thoroughly the product has been studied.

The advertising appropriation of engineering firms usually includes an item for exhibitions. These attract business men, including those from abroad, anxious to keep up-to-date in the particular industry and taking advantage of seeing a large part of a given market assembled under one roof. The exhibiting firm can not only show changes in design but demonstrate improvements in working methods. To get the best value out of the expenditure,

the firm must have technical representatives continuously in attendance to give advice and demonstrations, solve the problems of present or prospective clients and take part in the technical conferences usually held in association with engineering exhibitions. Some buyers may suggest modifications, and thus new designs may be accelerated. A proper set of reports must be sent to the sales manager for subsequent action.

The cost of publicity should be budgeted in advance, and the budget will depend on market research, as discussed in Book I (Chapter X). When deciding the advertising appropriation a campaign will be laid down based on the prospective sales volume, but, of course, subject to revision. As a rule isolated advertisements are worthless.

The examination of trade and technical journals is an important feature in sales promotion. On the one hand, the advertisements of Government Departments, municipalities, etc., indicate their requirements for tender, and a routine must be arranged for all tender forms of interest to the firm to be written for. On the other hand, the articles in technical journals will indicate new uses or outlets for the firm's products. Details of contracts placed, formation of new companies, erection of new works and various other news extracted from technical journals may also prove of interest to the firm.

SALES CORRESPONDENCE

Too much importance cannot be attached to correspondence, as a letter, in a way, carries the reputation of the firm with it, and may be the only means a prospective customer has of judging what kind of people he is going to deal with. Incoming letters must be acknowledged the day received if a complete answer cannot be given by return. All sales department's letters must be tactful, courteous and helpful, and every client must be made to feel that his enquiries are appreciated. If it is found that promises cannot be kept with regard to delivery date or other matter,

showing how they will affect the price. He will put his firm's technical experience at the client's disposal with a view to achieving a solution of the enquiry which will be the most economic in the long run and therefore redounding to the credit of his own firm in technical circles.

After an order has been placed, the representative must be ready for consultation whilst the job is being carried out and do all he can to facilitate and expedite its conclusion to the satisfaction of the client.

It is important for the firm to keep the representatives up-to-date with information, including complete and accurate facts about the products so that they can answer any reasonable question put up to them by customers. This information may take the form of data books, preferably the loose-leaf type so that new information can be recorded concisely and added as required or revised when necessary. The data books may be supplemented by a bulletin giving information which the representatives can utilize, such as improvements or enlargements in the firm's plants, data on competitive products, or advantages that have recently come to light with regard to the firm's own products, changes in prices or discounts, alterations in stocks or deliveries, notes as to slow or fast-moving lines, notices as to large or important contracts received, or any other information that will assist the activities of the sales force.

FOREIGN REPRESENTATIVES

A problem frequently arises as to the best type of man to choose for foreign representative or manager of a foreign branch. Should he be a man sent out from the head office, and if so should he be selected for his technical knowledge, owing to the distance he will be from the works, or should he be selected for his salesmanship and commercial knowledge or for his social standing? On the other hand, ought not he to be a native of the foreign country? Apart from the language difficulty, can an Englishman understand the

mentality of purchasers and the psychology of buying in a foreign market as well as a native? Will the engineers and other purchasers open up their mind to him as they would to a member of their own race? Will they not be more secretive to an Englishman who will have greater difficulty in understanding and forecasting the trend of events?

It is widely considered the better practice to place an Englishman in charge of a foreign branch and let him exert his ability to choose native assistants of the right type. This usually ensures that the interests of the parent firm are better safeguarded and the central policy more likely to be carried out. In any case, however, a member of the higher control should make regular visits as frequently as practicable, not only to study the position, but to familiarize himself with the special requirements of the country, to call on important customers and prospective clients, and to ensure a live and intimate connection between the firm and the foreign market.

ESTIMATING

Most of business life is one long series of estimates, and on the accuracy of estimates the success of the firm depends. In the following we are concerned with estimates of the cost of engineering work, and it may be thought that our specification for a successful estimator is too severe, making him a cross between a technician, a rate-fixer and a cost accountant, but the difficulty and importance of his job need no emphasis. He has to work prior to, and sometimes considerably before, an order is placed—obviously a more difficult task than the mere accumulation of costs after they have been incurred.

An estimate is the calculation of the anticipated or probable cost of a job or project if taken in hand. We are here more concerned with estimating as a tool of management than with the routine of the estimating office. It is apparent that estimating for an engineering project may

require far-reaching knowledge, and in competitive markets the work may have to be approached from the point of view of determining the possibility of performing a series of operations within a given time for a stated sum of money rather than a forecast of the manufacturing costs without reference to competitive possibilities and alternatives.

The importance of accurate estimating, apart from the danger of over-estimating in a competitive market, is to guard against financial loss. If under-estimating goes on for a period there is, of course, the danger of eventual failure. It is evident, therefore, that estimating must be based on practical experience, not only as a safeguard but because costs vary from plant to plant, and each must collect its own data.

The wide variations sometimes encountered in tenders for the same job arise from lack of reliable cost data, the fact that labour cost varies from shop to shop, depending on manufacturing efficiency, and that the overheads vary considerably from firm to firm. The main factors in direct costs are shop conditions and the nature of the work. Some firms may have available equipment which is most efficient for the purpose; jigs, fixtures, dies, patterns or other auxiliary equipment may be to hand; the quantities may suit the shop's capacity; the accuracy of work may be just what they are accustomed to, and so on.

The important points are to ascertain if the work can be handled with existing equipment without additional expenditure, and if the manufacturing methods are the most suitable for the job in view.

The most difficult work to estimate for accurately is repair work or new work, as experience may afford no data or check and a detailed estimate may be almost impossible to compile.

For standard products, estimating will be extremely accurate, and for any special work which involves some modifications of standard products accurate estimating should not prove difficult.

ORGANIZATION OF ESTIMATING DEPARTMENT

The estimating department should be divided into sections, each dealing with one product of the firm's manufacture or with the products of one manufacturing department. The advantage of specialization may be seen from examination of the procedure on receipt of an enquiry. The specifications must be examined, and any abnormal conditions, guarantee required, etc., must be noted. Drawings must be obtained, and quantities and weights determined with due regard for allowances and scrap. Parts to be bought must be decided upon, and their prices obtained. The work to be undertaken by the firm must be analysed with regard to the methods of manufacture involved, including a decision as to whether any new tackle, jigs or fixtures are required. The operation times must be worked out, and rates fixed so that the labour costs can be ascertained. The overheads must be allocated scientifically and not guessed. If any tests are specified the costs of carrying them out must be included. The estimate must be checked and compared with any established costs available for similar previous work.

It is obvious that if the work is to be done with expedition it involves collecting and filing data, classifying and tabulating them ready for use, the employment of graphical methods, and, whilst help may be obtained from department heads, sufficient technical and practical knowledge to know that the data are reliable and under what conditions they apply.

ESTIMATING STAFF

Apart from an ability to co-operate with the designing and works staff and the purchasing department, it is desirable that the estimating staff should have shop experience, as accurate estimating without experience is almost inconceivable. A man in the estimating department should have a good general knowledge of the plant and the capacity

of the machines, also a knowledge of the design he is estimating on and to judge if it is properly adapted to production. Otherwise he cannot analyse the shop problems involved nor forecast variables in costs, nor determine what proportion of the charge for drawings, patterns, jigs, tools, etc., should be included in the estimate.

He must be systematic in his work, have information readily available, and be capable of using rapid methods, as spot estimates may be on occasion a vital necessity to the sales department. Standardization will assist the estimator's work. He must, of course, be conversant with the inter-trading facilities possessed by his firm and the discounts allowed to them by their connections.

ESTIMATE OF MATERIALS

For any given enquiry a schedule of items is made and the price of each obtained, together with the time required to receive. Estimates are, of course, made out ahead of the work being put in hand; in fact, contracts may be offered for competition long before they are placed. Consequently, the estimator must be conversant with price trends and be able to forecast the probable market prices in order to make due allowances for price fluctuations in the tender. To this end he may make his own price charts or abstract from the technical press, for example from the *Iron and Coal Trade Review* for iron and steel. If prices are likely to alter, he may introduce a clause that the price is subject to revision after the lapse of a certain time, or he may state the basis price of the raw material and how any alteration will affect the amount of the tender.

An important part of the estimator's work is the taking out of quantities or estimating weights of materials. Drawings may only show the finished dimensions, whilst the estimate must take into account the rough sizes and weights. A practical knowledge of allowances and how they vary with size of product is essential for this work. Calculating the weight of castings and forgings may pre-

sent some complicated problems, whilst for an engineering estimate such diverse products as forgings, castings, girder work, plate work, brick and timber work may be included. The estimator must have a sound knowledge of common metals, their density, their price and their scrap value. To consider only pig-iron, wrought iron and steel, alloy steel, copper, bronzes, and brasses, aluminium and its alloys and bearing metals indicates that this is no light task. The estimator must also be conversant with British Engineering Standards.

He need not, of course, burden his mind with the enormous amount of detail involved in the above, but he must have all the data immediately accessible in his data books and files.

In estimating for accessories the estimator will make use of the firm's collection of engineering catalogues. It may be advantageous, although the firm can manufacture components or accessories, to obtain quotations from outside, as it will be a check on the firm's own estimates.

ESTIMATE OF LABOUR COST

The estimate of labour cost is more difficult than that of materials cost, especially if estimating is regarded in its proper light, that is, not carried out by guess work but by means of careful approximations, if not ascertained facts.

The planning department usually fixes the materials, production methods and sequence of processes, and the jigs, tools, and fixtures required as the type of plant used will affect the output and cost, but the estimator may on occasion have to do some of this work himself. The rate-fixer has the basic information and sometimes has worked out rules for the times required by various machines, but estimating is less a matter of rule than of judgment, reasoning, and knowledge based on past experience. The estimator must understand the governing conditions in a shop, consulting where necessary the superintendent or foreman, as there is not as a rule enough co-operation between the

production engineers and the estimator. It is no use, for example, estimating in the ordinary way if the shop conditions are such that overtime or night-work is necessary to undertake the stipulated delivery. The estimator must know the capacity of the machines as well as their performance.

The estimator will require to appreciate the difference between machining times and floor-to-floor times, the allowances for defective materials, the allowances for defective labour, and such items as the cost of marking off, the cost

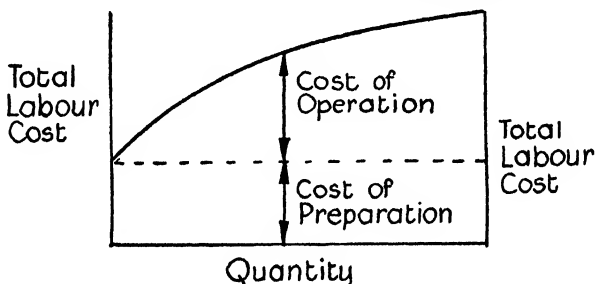


FIG. 61. DIAGRAM ILLUSTRATING THE EFFECT OF PRODUCTION QUANTITY ON LABOUR COST

of set-up, the cost of tools, the cost of inspection, the effect of multiple tooling, and so on. The effect of long runs on labour cost must be appreciated. It is clearly brought out in Fig. 61. The estimator must also know if the firm is manufacturing under licence so as to load on, if necessary, the royalty charge to the cost of production.

Let us suppose that besides being able to read specifications and drawings, having a knowledge of mensuration and a practical knowledge of shop conditions, the estimator has to do rate fixing for himself.

It will be useful for him to fix standard times for both machine work and hand operations, but this is possible only if he has experience and a knowledge of the capabilities of machines and tools and the character of the work. Suggestions may be given for formulae to use with certain

classes of work, but consideration of operating time is insufficient by itself and non-operating time must be taken into account, such as the supply of drawings, instructions, jigs, tools and gauges, the time for set-up, adjusting machine and tools, removal of work, and so on.

Provided tools are standardized, formulae may be developed for cutting speeds in rough turning and finishing, milling, drilling, screw-cutting, planing, etc., and so the time required for various jobs can be determined. It is, of course, assumed that before using the formulae for new work they have been checked up against the recorded times of operations within their range.

Standard times for hand operations are more difficult than for machine operations, but if the materials are standardized they can be attempted for filing, scraping, polishing, tapping, riveting, caulking, welding, and so on, in view of their value in estimating.

The estimator will have to understand the economics of grinding because, whilst greater accuracy and uniformity of finish can be obtained by grinding, problems may arise as to whether it is more economical to machine or to grind when accuracy, finish, labour cost, and machine charges are all taken into account.

The following factors will affect the decision: the amount of material to be removed, if the work can be done simultaneously with another operation, and if roughing and finishing cuts can be taken successively with the same tool or wheel.

To facilitate the work of the estimator, machine reference data must be kept up-to-date and accessible, and if machine cards are prepared as recommended in Chapter VII, but including the setting-up and adjusting times together with time-study information and other reliable data, they will prove useful in the present connection as well as to the production engineers.

Information on the following operations may be kept in loose-leaf books or might with advantage be diagrammat-

ized: sawing, turning, drilling, boring, reamering, shearing, milling, planing, shaping and slotting, gear cutting, grinding, centreless grinding and polishing, with times for setting-up and removing work, heat treatment, welding, oxygen-flame cutting, die-casting times, handwork, erection, and so on.

The estimator has to convert operation times into money values, so that he has to know the rates of the various classes of labour, which he may well keep tabulated. He must be conversant with the wage system extant, whether individual, payment by results or collective bonus, and the effect it has on the labour cost. Besides tabulating the rates per hour, he may find it advantageous to collect data on the cost of removing metal per lb. or treating it per square foot, as for example in the operation of grinding.

ESTIMATE OF OVERHEADS

Overhead charges are the most difficult portion of an estimate, and it is mainly due to variations in these charges that differences in prices quoted by competing firms arise. The oncost charges will be decided by the cost accountant of the firm—in fact, it is difficult to see who else could advise on establishment charges—but the estimator must be conversant with what oncosts are, how they arise, how they decrease with increasing production, and how they should be allocated.

He must know that overheads consist of factory expenses, selling expenses and general or administrative expenses, though it will be the first-named with which he is more directly concerned. The estimator must appreciate that a general overhead on the whole of a factory's production is to be condemned, and if it is impossible to allocate overheads by products they should at least be departmentalized. As overheads are such a vital factor in competitive tendering, the estimator must understand the importance of ascertaining under whose control the overhead charges

fall, so that responsibility can be fixed and efficiency of management checked. In choosing between the various methods of allocating workshop expenses, the estimator must try to determine what is the factor most nearly correlated to these expenses; for example, in choosing between the machine-hour and the man-hour methods, is the machine or the operator the controlling factor? He must also appreciate why different methods of allocation are used for different shops, such as the pattern shop, the foundry, the smithy or forge, and the machine shop.

The headings under which he draws up the estimate sheet vary with the class of production, but the following may be suggested—

Description	Quantity	Material			Operations	Wages
		Finished Weight	Gross Weight	Cost		
Workshop Expenses	Establishment Charges	Packing Charge	Delivery Charge	Total Cost	Profit	Price

Packing and shipping will receive the estimator's attention in order to secure the most economic charge. There may, for example, be alternative methods of packing and there is no need to go to more expense than necessary, such as packing as if for export when the goods have to be delivered in this country. Certain orders may, however, call for special packing, and the estimator must allow for this. His records may yield the cost of freight, but it is probable that he will consult the traffic department as a good deal of specialized knowledge is involved in determining the cheapest transport method and route. Moreover, the traffic manager may be able to make the consignment part of a car-load and so obtain a cheaper freight rate, or advise on the most economic size and weight of package.

ESTIMATING PROCEDURE

Let us now recapitulate the procedure from the receipt of an enquiry. The planning department (of which the

drawing office is assumed to be a section) will set down the requirements and specifications, and types and quantities of materials, look out or make out the drawings, and probably lay down the methods and sequence of operations.

The job specific to the estimating department is—

(1) To determine the weight of all materials, including all allowances.

(2) To determine the cost of materials either at market price or a forecasted price, or at a basis price with a statement of allowances for variations.

(3) To determine the price of outside purchases and how soon they can be obtained.

(4) To determine the labour cost of each operation from performance times and wage rates, including manufacturing and assembly, also testing and erecting if necessary.

(5) To determine the cost of any auxiliary equipment necessary and how this cost is to be spread.

(6) To make contingency allowances based on experience.

(7) To determine the time of delivery in collaboration with the progress department; if a definite delivery date must be guaranteed, to ascertain if overtime or night work is necessary and make corresponding adjustments.

(8) To determine the factory oncost in collaboration with the cost office.

(9) To ascertain the general overhead from the accountant.

(10) To check by comparison with similar work.

(11) To examine any guarantees, conditions and special points, e.g. with regard to delivery, and see that they can be met.

(12) To determine packing charges.

(13) To determine delivery charges and cost of insurance in transit if necessary.

(14) To add the standard profit and submit the estimate to the directors for their decision.

(15) To hand the estimate to the sales department for dispatch of the quotation or tender.

With reference to point (14), the percentage added for profit is very frequently a matter of policy. The price quoted largely depends on trade practice. If the trade is of a monopoly character, the price may have no relation to cost, but in ordinary competitive industries it will, of course, be conditioned by the cost of production. The percentage profit added will usually depend on the quantity of goods ordered, but even further concessions may be made to certain customers. In tendering for foreign work the profit added is usually higher to offset inconveniences of irregularity in currencies and other uncertainties. In general, it may be said that the larger the contract offered, the larger will be the radius over which tenders are received and the greater the tendency to cut profit margins. If complete specifications are supplied the tendency is also to cut prices, but if a general specification is issued firms generally specialize in offering the best design and specification and let the price take care of itself.

If a tender has to be itemized, a small profit is put on parts of which many are required and a larger profit on parts of which only a few are wanted.

An example of a simple estimate may be given as follows:

ESTIMATE FOR 1000 SPECIAL STEEL AUTOMOBILE VALVES

(1) Material: Twenty-one 10-foot lengths, centreless ground . . . £13	Each 3d.
(2) Wages. Forge Shop. Cutting to length . . . ½d	
Upsetting . . . 1½d	
	-- 2d
Machine Shop. Milling head and cotter slots . . . 1d.	
Heat treatment . . . ½d.	
Grinding head . . . 1½d.	
Grinding seat . . . ½d.	
	-- 3½d 5½d
(3) Cost of new die . £4	1d
(4) Workshop Expenses: 200% on forge wages . . . 4d.	
150% on machine shop wages . . . 5½d	
	-- 9½d. 9½d.
(5) Total Factory Cost	1/6½d.

(6)	Establishment Charges. 25% Factory Cost	4½d.
(7)	Estimated Cost	1/11½d.
(8)	Packing and Transport	½d.
(9)	Profit	3½d.
(10)	Price. Quote	2/3d.
(11)	Delivery: 7 to 10 days	

TENDERS, ADVERTISEMENTS AND SPECIFICATIONS

A tender is a written offer to do work or to provide goods at a definite price, and if accepted there is, of course, a contract. We have discussed contracts in general terms in Book I (Chapter VII), but the following notes refer more particularly to engineering contracts.

In the case of a trading company a written note signed by a person under the express or implied authority of the company is sufficiently binding. A letter accepting the tender will (with the tender) constitute a contract. Each tender should contain the manufacturer's specification and a printed list of conditions of sale. From the purchaser's point of view it should contain a clear statement as to liability for non-fulfilment of performance, and for damage in transit and maintenance during the initial period of service, and from the seller's point of view the terms of payment required.

Unless the standing orders under which a public authority acts provide otherwise, notice of a contract to be placed by the authority must be published and tenders invited. (The Local Government Act, 1933.)

The specifications used must define fully and clearly the requirements, for example—description of plant, its duty, testing, erection, delivery, conditions at site, materials covered by British Standard Specifications and the limits of the contract in relation to other contracts.

Model forms of general conditions of sale are available and recommended by the leading engineering institutions. The contract with a public authority will comprise the specification, the general conditions, the accepted tender, and the memorandum of agreement.

As mentioned above, in some cases contracts to be placed by public authorities must be advertised. The advertisement will declare the general description of the work and the approximate quantities, where to apply for form of tender, specification drawings or plans, the character of the bids desired, the person to receive the bids, when and where, the conditions of payment, the security required, if any, and the right to reject bids. Bidders get all their information from the drawings and specification, and if properly drawn up it should be unnecessary to ask for additional information.

Specifications may vary from bare outlines to elaborate statements, but they should in any case be expressed in simple and exact language. The specification must not be too rigid. It is inadvisable when dealing with machinery and plant exclusively to specify components or auxiliaries. With regard to design, a clause should be included permitting "other approved design." It is preferable to specify performance rather than physical and mechanical requirements as this allows diversity of raw materials and makes possible improvements to mutual advantage.

In regard to the form and arrangement of the specification, the general clauses as to responsibilities and terms generally precede the specific clauses as to design and construction.

In specifying machines of standard design, the requirements may be set out in great detail, but for special machines the specification should go no further than general description and conditions. The specification will contain particulars as to inspection or survey and usually it contains a clause that the work is to be completed to the satisfaction of the engineer or agent.

It has been said that the tender form and specification should be clear and definite. They should be well written but not literary. The bidder should examine all clauses carefully, and set out his offer equally clearly. The tender should be submitted by the due date or it will not be

considered. In conclusion it may be useful to capitate the most important points requiring attention—

General description.

Particular description.

Conditions of sale.

The limits of the contract.

Are drawings or samples to be submitted?

The requirements as to inspection, testing or performance.

The conditions of acceptance.

Packing and dispatch.

Delivery; place, date and order or progress of work.

Conditions and procedure for extension of time.

Terms of payment.

Responsibilities of the contractor.

Storage if necessary.

Damage in transit.

Guarantees.

Penalties for non-fulfilment.

The purchaser's right to suspend.

Arbitration procedure if necessary.

The legal construction of the contract.

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